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The effects of color, exposure time, and target density on tactical display recognition tasking

Concannon, Thomas Joseph; Rowell, Julie Anne

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THE EFFECTS OF
COLOR, EXPOSURE TIME, AND TARGET DENSITY
ON TARGET DISPLAY RECONGNITION TASKING

by

Thomas Joseph Concannon

Julie Anne Rowell

September 1986

Thesis Advisor: D.E. Neil

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The Effects of Color, Exposure Time, and Target Density on Tactical Display Recognition Tasking

by

Thomas J. Concannon
Lieutenant, United States Navy
B.S., U.S. Naval Academy, 1979

and

Julie A. Rowell
Lieutenant, United States Navy
B.S., Calif State University, Long Beach, 1979

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ABSTRACT

This study investigated the effects of a partially redundant color code on a visual search task. Monochrome and partially redundant color displays consisting of NTDS symbology, in concentrations of 18 targets and 36 targets, were displayed for 10 seconds and 60 seconds. Subjects were asked to reconstruct the plots immediately after viewing. The addition of color partial redundancy resulted in an overall enhancement of performance of 14.1% over the monochrome display.

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I. INTRODUCTION

A. HISTORICAL BACKGROUND

Any task requiring the accurate retention of information by any means, including human memory, involves some form of coding. Basically a code is a collection of symbols for sending messages or storing data. Codes have been used since the time of early man. Cave scratchings, notches on a stick, hieroglyphics, modern alphabets and number systems are all codes. Militarily, some applications of codes have been to send battle orders, report on victories or defeats, transfer needed operating information, and to display the tactical situation.

In ancient times, most engagements were on a scale which allowed a commander to stand atop a convenient hill and control the movement of forces simply by visually observing the battlefield and sending the needed orders to his field commanders. A classic example of this occurred in 480 BC when King Xerxes of Persia was enthroned upon a cliff to watch the Greeks defeat the Persian Fleet at the Battle of Salamis. (Potter, 1981, pp. 2-5) As warfare progressed, both the numbers of units involved and the size of the battlefield grew to the point where a commander could not hope to view all actions from a single vantage point. This lead to the use of maps and charts to display the tactical battle area and the use of various locally developed symbols to represent the units involved. At first runners where used to carry information to the commander's location for inclusion in the tactical display. As technology improved, so did the means of getting information to the commander, and likewise the amount of information also increased.

Today, the amount of information available to a commander is phenomenal. It is transmitted electronically to his flagship or command post and is continually updated, often in near real time. This requires a maximum amount of system integration and coordination to insure the data is both available and put to the optimum use. The current situation in the surface navy is aptly described by Friedman (1986, p. 82):

> In the past, integration was manual; different radars, for example, fed into a single vertical summary plot in the combat information center (CIC), and a ship was fought on the basis of that integrated plot. The information was transmitted manually . . . In a confused and rapidly changing situation, manual contributions can become inaccurate and the plot can be saturated. NTDS was

invented in the 1950s to solve this problem; radar operators individually enter their contacts electronically, so there is no intervening plotter or talker.

The US Navy has adopted a specific set of symbols to represent tactical information, it is commonly referred to as the standard Navy Tactical Data System (NTDS) Symbology and is shown in Appendix A. Of primary importance are the locations of all contacts, their classification (friendly, neutral,or hostile), type (air, surface, or subsurface), and their movements. Currently, the NTDS displays are monochrome phosphor green displays of the appropriate contact symbols on a polar projection. When using NTDS, as with using any code, the challenge is to be able to retrieve the needed data from the visual display quickly and accurately. This requires the optimization of coding, taking into account the way people view the displays (physiology) the way they interpret what they see (psychology), and the limitations of the equipment involved (technology).

B. CODING

"A code is generally typified by a set of stimuli or symbols that represent in some specified manner events in the external world." (Jones, 1962, p. 355)

A great deal of work has been done in trying to determine what type of coding or combination of coding schemes will allow a human operator to perform a given task with the greatest speed and accuracy. The most prevalent coding schemes involve alphanumeric, symbolic, acoustic, color, or any combination thereof. When code schemes are combined, for example: color coded symbols, redundancy can occur. When the two coding patterns provide the same information and can be utilized independantly of each other, this is total redundancy. In the case where one coding pattern supplies only part of the information and acts to help reduce uncertainity, while the other supplies all of the needed information, the code is then referred to as partially redundant. (Teichner, 1977)

Experiments suggest that the use of combination codes (redundant or partially redundant) can increase the amount of information transferred either by increasing the alternatives or improved discrimination between the existing alternatives presented. (Jones, 1962, p. 357) Redundancy coding also tends to improve the reliability of the information extracted and lowers the time needed to respond to the information when presented. (Burdick, 1965, p. 4) When utilizing redundant coding techniques it is critical to avoid overcoding, this tends to require the user to spend more time reviewing the code than in using the information it presents. (Oda, 1977, p. 81)

A well thought out and properly implemented code can increase the effectiveness of a Commander's decision making process. However, there are occasions when there can be too much coding:

> . . . any coding operation that is intended to enhance the discriminability of targets may also enhance any distracting effects due to nontargets. . . the greater the number of nontargets, the greater would be the potential inhibition . . . A search code must be judged on its ability to separate targets from nontargets under various levels of display density. (Jones, 1962, p. 360)

Research has suggested that there are three key parameters that exist in determining the value of a coding scheme. These are the exposure time of the individual to the display, the density (number of informational data points) present, and the specific response demanded of the operator. (Jones, 1962, p. 359)

The visual display is utilized as a tactical decision aid for such 'response required' tasks as search, identification, localization, counting, and verification. (Kantowitz, 1983; Luder, 1984). A search task can be defined as one in which the operator knows the categories in advance and his or her task is to locate them correctly on the display. Identification requires identifying targets as to type (air, surface, subsurface) and threat (friendly, hostile, neutral). Localization tasks involve determining a given targets bearing and range in relation to own ship, or a preselected grid reference, which is known as the Data Link Reference Point (DLRP). Counting is simply determining how many targets are present. Verification requires a means of positively identifying targets, as by IFF (Identification, Friend or Foe) or backing up data obtained from another sensor, for example, radar locating a target on a Electronic Warfare signal intercept bearing.

C. VISUAL DISPLAYS AND COLOR CODING

> Visual search displays present complex coding problems the resolutions of which seem to depend on the particular attention getting qualities of a code continuum... This may explain the effective use of color as a means of reducing display clutter when used as a partially redundant code. Even in search situations without redundant coding, color facilitates target location. (Jones, 1962, p. 362)

An examination of the literature by Oda (1977, pp. 195-197) determined 12 specific selection criteria that apply to coding as related to tactical displays:

1. Displays are easier to interpret if qualitative codes (shape, color) present qualitative information (type, condition) and quantitative codes (size, numbers) present quantitative information (course, speed).

2. Priority in code choice should be based on the number of information steps encoded. For example: using three color steps to represent hostile, friendly, and neutral contacts.

3. Past proven codes in similar tasks should be used whenever possible.

4. Priority should be given to standardized codes and group stereotypes to enhance recall. Example: red for hostile contacts and the standardized NTDS symbols.

5. Use nonredundant coding whenever possible. Use partial redundant coding to separate signals from noise in highly cluttered displays.

6. Use dissimilar codes on the same display to avoid confusion. Do not encode several kinds of information with the same code.

7. The code should be compatible with the environment it is to be used in. For example: using an audible alarm in a high noise environment is inappropriate. A flashing red strobe in the same environment would be appropriate.

8. Codes should be compatible with the capabilities of the operator. In a tactical environment, the avoidance of complicated codes that require a great deal of concentration to understand should be avoided.

9. Chosen codes should conserve display space.

10. A code's attention getting capacity should be proportional to the importance of the coded information.

11. Codes which allow for ordering of importance should be given precedence over those that do not.

12. Codes should be able to be implemented easily with the available hardware and software.

Color coding involves the use of various colors to define the elements of information being presented. A typical human operator, with average color perception can distinguish approximately 150 separate shades of color across the visible spectrum from the reds to the violets. (Krebs, 1978). Computer color chips can produce a virtually unlimited range of color shadings by varying saturation levels on a typical average of 16 separate colors. When using color as an enhancement, it is recommended that not more than four colors be used at any given time. (Oda, 1977, p. 172) To limit the possibility of mistaken interpretation by an operator, the colors used should be separated in the visual spectrum enough to avoid having to distinguish between shadings of a single color. Red, white, yellow, blue, and green on a dark background are the most commonly utilized colors codes. (Oda, 1977) An additional factor to consider is relating choice of color to traditionally accepted meanings associated with that color, for example: red tends to be representative of danger or threat.

Research has shown that color coding is useful in situations where the display is unformatted, symbol density is high, and legibility may be degraded (Krebs, 1978, p. 44). Studies have also indicated that color coding is most applicable to two types of tasks, namely search and identification (Luder, 1984, p. 19). These are precisely the tasks performed when using a tactical display system.

A color code used in conjunction with a shape code could enhance the ability of the operator to search out and identify specific classes of targets (friendly, neutral, or hostile). An additional benefit may accrue from the man-machine interface involving the operators eye and the display. On the standard NTDS display screen, average symbol size is .125 inches. The eye is capable of distinguishing shapes down to a size of .15 inches (Oda, 1977, p. 173). It is understandable that errors in distinguishing shape would be highly likely in a high density, stressful environment such as a tactical engagement. The addition of a partially redundant color code could backup the current shape code, identifying a targets classification. The shape would still be needed to determine the specific type of target involved.

Color is not presently employed on any NTDS display screens used by the Battle Group Commander. Current microcomputer installations aboard ship are beginning to use color displays to enhance data recovery and provide some esthetic enhancement to these displays.

The inherent complexity of a tactical display system suggests the utilization of the most efficient coding system possible. The limited categories (neutral, friendly, or hostile) and possibilities for target classification (surface, subsurface or air) lend themselves ideally to a partially redundant coding scheme. The visual graphic format is ideally suited to the use of color as one of the key elements. A potential method of achieving the required level of efficiency involves using the current NTDS symbology combined with a color code.

In an attempt to improve the current NTDS display by addition of color, the following situation is possible. The primary application of color could be to distinguish between friendly, neutral and hostile target sub groups. This would require only three colors. The choice of colors should follow traditionally established color schemes in the attempt to enhance search times and the ability to recall target locations by the operators. This traditionally accepted system is RED for HOSTILE contacts, GREEN for NEUTRAL contacts, and BLUE for FRIENDLY contacts. Current CRT technology permits the use of these three colors with adequate saturation to permit distinguishing between them under the present lighting conditions in fleet CIC's.

In the preceding pages, background material has dealt with the mechanics of coding, both in general and specifically dealing with the Navy's system of NTDS. In order to fully evaluate the effectiveness of an additional partial redundancy (color), it is necessary to understand the human mechanisms involved in code processing. As well as the method used by individuals to organize the available data.

D. CODE PROCESSING

Every glance at a newspaper, a television, or a CIC tactical display results in information being processed by the brain. However, every piece of information is not handled with the same priority or at the same speed.

Experimental research (Teichner, 1977, pp. 12-13) has shown that certain codes have a higher processing priority than other codes. For example, an alphabet (shape code) has a higher priority than color dots (color code). This result can be attributed in part to the user's familiarity with a given code. The alphabet has been part of an individual's environment since early childhood, while a colored dot code would have had much less exposure time. This priority of processing seems to operate on this familiarity. The more familiar a code, the higher the priority. Even if the code is not part of the daily environment, shape codes seem to have higher priorities than other codes, such as color. The importance of these priorities comes into play when the code has multiple parts (i.e., shape and color). Different priorities can exist which may cause part of the code to be overlooked or processed at a later time. If this code uses its separate parts to transmit different information then problems could result: such as the loss of information or incomplete information which can cause delays in the decision making process. On the other hand, if the code is partially redundant then multiple paths can exist for the information to be processed by the user.

Codes (or parts of a code) can be processed at different speeds. The speed difference is assumed to be caused by the processing method used by the brain. When the brain processes information one step at a time, the method is called serial processing. If the brain can process the information over several steps simultaneously, the method is called parallel processing (Norman, 1969, p. 8). Several experiments (Luder, 1984, pp. 21,31; Saraga, 1973, p. 265) have indicated that color undergoes parallel processing and shapes undergo serial processing.

This dual processing mechanism can lead to interference between codes. A color which is an irrelevant factor will be processed faster than a relevant shape factor, even

if the user has a different processing priority. The interference could degrade the information flow. On the positive side, use of color as a revelant factor could increase the information flow rate. If the color was partially redundant, then the information flow rate could increase, though it would be incomplete.

E. CHUNKING

When presented with a visual display, the user can be more efficient when he organizes the information into discrete groupings called chunks. This chunking strategy occurs regardless of the type of code used in the underlying physical mechanism that transfers the information to the brain.

The strategy for developing these chunks can be based on numerous relationships. Some of the more common ones are (Badre, 1982, p. 497):

A) Classification relationship: such as grouping together all the circles in a display.

B) Spatial/Geometrical relationships: such as grouping by quadrants, or by locations relative to each symbol.

C) Tactical relationships: each piece of data has a meaning and can be associated with other pieces of data through that meaning.

One measure of effectiveness (MOE) of a code is in its information transfer ability; or in other words, how easily can the user group the code into information that can be used to make decisions. The type of MOE is directly related to the effectiveness of the chunking strategy being used by the individual (Kanarick, 1971, p. 188). The more effective the chunking, the better the individual will perform.

Research has shown the one of the primary factors influencing the effectiveness of a code is the experience of the user. An individual who understands and has worked with a system (i.e., the real world that the code represents, as well as the code itself) can develop more relationships between pieces of data (Badre, 1982; Frey, 1976, p. 542). The more relationships that can be formed, the larger the chunk which can be processed. In addition, the experienced user can see relationships between chunks which makes using the information easier. Chunking can cause greater efficiency, as the more experienced user can gather more information in shorter periods of time. It is believed that by using well defined chunks, the user either entirely bypasses the Short Term Memory (STM), or quickly goes through STM (Frey, 1976, pp. 545-546) to Long Term Memory (LTM). STM is the working memory of the brain, having a very limited capacity for data. LTM is the final storage place for all information processed

by the brain. (Kantowitz, 1983, pp. 174-175). If all the information needed to make a decision is in a well defined chunk, the process of retrieval from LTM is simplified, and the decision making process time decreased.

In summary, different types of codes, or code combinations, have an effect on the ultimate purpose of a code: information transfer. With the increasing complexity of information available to a tactical decision maker, as well as the multiple tasking stresses, a military code must take advantage of all aspects of the processing and chunking mechanisms. The question of this thesis is whether multicolor partial redundancy will aid in the efficiency of the NTDS code.

Color could conceivably aid in information transfer in two ways. First, by speeding up the processing time of the code. A decision maker will look at a display, then look away to perform some other task. To ensure maximum efficiency, the time required for the user to find the symbols of interest after this break (i.e. search time) should be a minimum. Color has been shown to decrease search time (Burdick, 1965, p. 27). Second, color could improve chunking techniques by providing additional strategy paths. These paths could result in larger chunks, decreasing the time required to organize the chunks, and better/more relationships between distinct chunks.

II. EXPERIMENT DESIGN

A. OVERVIEW

As discussed at the end of Chapter I, the primary objective of this thesis was to determine the effect of partially redundant color coding on a search and identification task. To achieve this objective, several key variables were identified that affect performance in a search and identification task. If the partially redundant color code has an effect (positive or negative) in this type of task, then it should show up in an analysis of these key variables. The key variables were:

1. display density (number of targets present)
2. viewing time
3. chunking methodology

Development of the experiment led to several hypotheses concerning the principal variable of partially redundant color coding, as well as concerning the key variables. Basically, the null hypothesis was that partially redundant color coding would have no effect on the subject's ability to perform the assigned task. The alternate hypothesis was that partially redundant color coding would have an effect, either positive or negative. This effect would be reflected by an increase or decrease in the number of correct responses relative to a control group. These null and alternative hypotheses were applied as the key variables were changed. In other words, partially redundant color coding would have no effect as display density varied, view times changed or on chunking techniques.

In addition, several underlying hypotheses were tested, with respect to the key variables. For display density, the null hypothesis was that the number of targets present on a given display would not effect the performance of the subjects. The alternate hypothesis was that a change in display density would effect performance. The null hypothesis for viewing times was that varying viewing time would have no effect on performance. The alternate hypothesis stated that viewing times would effect performance. Any change in performance would be determined from the number of correct responses--which will be defined shortly.

Finally, it was assumed that some form of chunking would be employed by the subjects. Three specific types of chunking were looked for: classification, geometric and tactical. Chunking by classification was assumed to be very likely, the subjects were able to chunk by threat type (i.e. submarines, or aircraft etc). This technique could result in some type of hierarchy of responses, which could be analyzed for tactical relevance. The second possibility was chunking by geometric location. This would be indicated by more correct responses in a specific region of the display than in other regions. Third, chunking could occur based solely on tactical significance. In this case, correct responses would relate to various types of contacts and their relationships with each other.

As mentioned, this experiment has several areas of cross analysis. To clarify the setup, Table 1 shows all tests and interrelationships.

B. GENERAL DESCRIPTION OF EXPERIMENT

Due to the time demands on the available subject population, the experiment was designed to allow maximum data collection, in the shortest amount of run time. The experiment consisted of the subjects reading a short descriptive scenario concerning their duties, followed by the subjects viewing several tactical displays. Immediately after viewing each display, the subjects were asked to reconstruct it on blank plots. Upon completion of this reconstruction phase, the subjects were asked to copy a display. The final phase involved filling out a short questionnaire. Examples of the material provided to the subjects is shown in Appendix A. Each run involved 2 to 3 subjects and lasted approximately 20 minutes.

C. DETAILED DESCRIPTION OF THE EXPERIMENT

1. Scenario

The scenario was written to establish the "duties" of the subjects when viewing the projections. The primary intent was to establish a tactical situation (antisubmarine warfare related) which would allow the subjects to tactically chunk if they wanted to.

2. Displays

The displays consisted of polar plots with NTDS symbols at various contact locations. The plots were centered at an arbitrary point with four concentric range rings. North-south and east-west lines established four quadrants. The displays were created using a Commodore 64 personal computer and a graphics software package. Each display was generated on a 320 by 200 pixel high resolution color monitor.

TABLE I

EXPERIMENT TESTS

Constants		TIME		DENSITY		COLOR		CHUNKING			
		60 s	10 s	SAT	UNSAT	M	C	T	G	TG	Q
TIME	60 s	■				■	■				
	10 s		■			■	■				
DENSITY	SAT	■	■	■		■	■	■	■	■	■
	UNSAT	■	■		■	■	■				
COLOR	M							■	■	■	■
	C							■	■	■	■

M = Monochrome
C = Color

T = Type
G = Group
TG = Type + Group
Q = Quadrant

Two basic displays were shown. The first display was an 18 target (unsaturated) plot; the second was a 36 target (saturated) plot. The number of targets used for each display was based on similar experiments by Badre (Badre, 1982). In addition, each display was duplicated in monochrome (green on black background) and in color (red, green, and blue symbols, white plot on black background). These displays are shown in Appendix A.

To allow some flexibility in conducting each run, the displays were photographed on 35mm color slide film. The camera was set up approximately two feet in front of the screen using a 50mm lens at F1-8. The film was at ASA 400, with an average exposure time of 4 seconds. This exposure time allowed the individual pixels to record on the film. The problem with this exposure time was that the film's color balance tended to change: the colors faded. To correct for this problem, the slides were touched up with transparency markers. In the monochrome case, the entire slide was tinted green.

Each surface symbol on the display occupied a 7X7 pixel image area, the air and submarine contacts occupied a 7X4 pixel area. Appendix A, Figure A.2, maps each symbol by pixels utilized. Each symbol was used the same amount of time 2 of each symbol in the unsaturated display, 4 of each symbol in the saturated display. This would allow for comparisons between specific threat types as well as threat categories.

3. Environment

Each run was conducted in a classroom setting. Due to high utilization of classrooms, the exact location varied from run to run. In every case, the room was darkened to allow viewing of the displays by test subjects. The projector was set up at eye level to allow a flat, distortion free display. Each run display averaged three feet across the polar plot.

4. Reconstruction Phase

To allow for accurate comparisons between monochrome and color display effects, each run consisted of only one mode, (only color displays or only monochrome displays). Thus the subjects were either part of the control group or the prime variable group.

Within each run, viewing time and saturation levels were varied. Subjects were first shown the unsaturated display for 10 seconds, then were asked to reconstruct it. This same procedure was followed for saturated, 10 seconds. No time limit was placed on the reconstruction.

Since the displays were not to be varied between exposure times (contact location remained the same) an attempt was made to distract the subjects and prevent recall between the two phases of the run. This distraction consisted of a series of questions, and then the viewing of several naval slides. By disrupting the flow of the experiment, it was hoped that the subject's STM lost the data from the first phase.

The second series showed each slide for 60 seconds, followed by a reconstruction. In an attempt to avoid prejudicing the subjects towards or against the color code, the subjects were provided with color pens (red,green and blue) for use during the reconstruction. No instructions were provided on the use of those items.

5. **Copying Phase**

In order to establish a baseline for determining the type of chunking being used, the subjects were required to copy the saturated plot while being observed by the experimenters. The purpose of this task was to observe how often the subjects referred to the display for information and to see the method they used to copy the display.

To record the times, a program was written for a Radio Shack M-100 computer to allow single keystroke entries. These entries would record each subjects identity and the time of each look. While one experimenter was performing this task, the second experimenter noted the pattern and number of targets recorded with each look. Due to this procedure, each run was limited to 2 or 3 subjects.

6. **Questionnaire Phase**

The final phase of the experiment run required each subject to fill out a questionnaire. This questionnaire tried to determine each subject's subjective analysis of the chunking method used, the effect of time, the effect of saturation and the effect of color.

III. DATA ANALYSIS

A. POST EXPERIMENTAL DATA ORGANIZATION DESCRIPTION

The experiment was conducted utilizing subjects available at the Naval Postgraduate School in Monterey, California. Twenty Junior Naval Officers participated in the experiment. The subjects represent a random sampling of the typical personnel who would be called upon to employ tactical plots similar to those utilized in the experiment. The sample population profile included Lieutenants and Lieutenant Commanders from all major warfare areas (surface ship, submarine, naval aviation, and ashore technical staffs) and with varying degrees of familiarity with NTDS symbology (ranging from none to a great deal). A detailed profile of the twenty subjects is included in Appendix A (Table 25).

The twenty subjects were divided evenly between the two primary test cells. As has been previously indicated, the experiment had to be conducted in small groups to facilitate proper and essential data recording by the experimenters. To limit the effects of nuisance variables, such as environmental differences (lighting, noise levels, etc.), the experiments were conducted in similar classrooms, with similar ambient noise levels. The various subject groups were all given identical initial indoctrination briefs at the beginning of each experimental run. The only indoctrinational differences occured between the two primary cells (color and monochrome). In the color case the subjects were told that colors would be used, and which colors went with which threat symbol type; i.e. Friendlies were Blue, Hostiles were Red, and Neutrals were Green. The control group was informed all symbols would appear in a monochromatic shade of green. Additionally, to avoid prejudicing the subjects as to the relative importance of color in their decision processes and reconstruction efforts, the color group was supplied with red, green and blue pens while the control group was supplied with just green pens. In both test cells, the order of presentation of the displays was identical and as follows:

1. 10 Second Unsaturated Display
2. 10 Second Saturated Display
3. 60 Second Unsaturated Display
4. 60 Second Saturated Display
5. Saturated Display Reconstruction

The subjects were given an opportunity to ask questions at the beginning of the test run to clarify what was expected of them. Questions concernin g the use of colors, methods to be employed, or what grading criteria were being employed were not answered. All subjects had thesame basic information concerning the experiment and its purpose priorto their being tested.

Upon completion of each test run, the individual subjects turned in 5 plotting sheets, corresponding to the 5 items in the order of presentation a personal data summary, and the questionnaire described in Chapter II. At the end of the experiment, there were 80 plotting sheets to be graded for correctness of responses and 10 plotting sheets and questionnaires be analyzed in determining chunking methods.

In grading the plotting sheets, a response was considered 'correct' if it was the correct symbol and in the correct location on the polar plot. The plotting sheets were graded by just one individual to reduce any biasing errors in determining what constituted a 'correct' response. Upon completion of grading the resulting data was

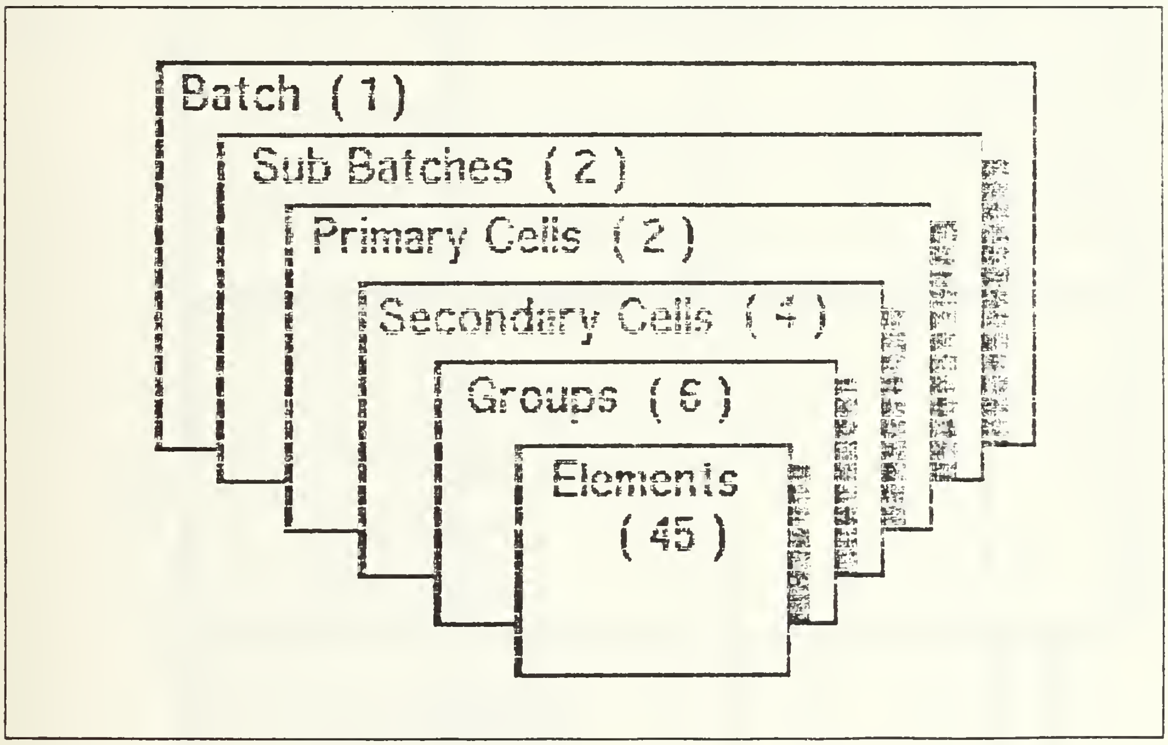


Figure 3.1 Analysis Units.

organized into manageable analysis units according to Figure 3.1.

Constants		TIME 60 s	TIME 10 s	DENSITY SAT	DENSITY UNSAT	COLOR M	COLOR C	CHUNKING T	CHUNKING G	CHUNKING TG	CHUNKING Q
TIME	60 s	MS v CU MU v CS				S vs U	S vs U				
TIME	10 s		MS v CU MU v CS			S vs U	S vs U				
DENSITY	SAT	M vs C	M vs C	M10 v C60 M60 v C10		10 vs 60	10 vs 60	√	√	√	√
DENSITY	UNSAT	M vs C	M vs C	√	M10 v C60 M60 v C10	10 vs 60	10 vs 60				
COLOR	M							√	√	√	√
COLOR	C							√	√	√	√

M = Monochrome
C = Color

T = Type
G = Group
TG = Type + Group
Q = Quadrant

Figure 3.2 Areas of Comparison.

Figure 3.2 details the Specific Areas of Comparison utilized in the Data Analysis. Where appropriate, the actual cell comparisons are noted within the figure. In the case of chunking, methods of analysis are described elsewhere in the text.

The BATCH consisted of the total number of correctly located symbols, regardless of type or group, on each plot, for ALL TEST SUBJECTS.

The SUBBATCHES were created by subdividing the batch by the total number of correctly located symbols for those subjects FAMILIAR with NTDS (SubBatch 1), and those NON-FAMILIAR with NTDS (SubBatch 2).

The PRIMARY CELLS divided the data between those completed with MONOCHROME (cell 1) or MULTICOLOR (cell 2) Symbology.

The SECONDARY CELLS further subdivided the data by density into SATURATED or UNSATURATED cells; and by time into 10 second and 60 second cells.

The GROUPS and ELEMENTS were the finest subdivisions utilized in the analysis. The following list details these. In each case, the Element represents the number of correctly plotted responses is the indicated category.

E 1. All Symbols

G 1. Symbol Group
- E 2. Air
- E 3. Surface
- E 4. Submarine

G 2. Symbol Type
- E 5. Friendly
- E 6. Hostile
- E 7. Neutral

G 3. Symbol Type and Group
- E 8. Friendly Air
- E 9. Friendly Surface
- E10. Friendly Submarine
- E11. Hostile Air
- E12. Hostile Surface
- E13. Hostile Submarine
- E14. Neutral Air
- E15. Neutral Surface
- E16. Neutral Submarine

G 4. Quadrant
- E17. Upper Left (First)
- E18. Upper Right (Second)
- E19. Lower Left (Third)
- E20. Lower Right (Fourth)

G 5. Circle
- E21. Circle 1 Inner Circle
- E22. Circle 2
- E23. Circle 3
- E24. Circle 4
- E25. Circle 5 (Outer Area)

G 6. Circles and Quadrant

E26. Quadrant 1 Circle 1
E27. - Circle 2
E28. - Circle 3
E29. - Circle 4
E30. - Circle 5
E31. Quadrant 2 Circle 1
E32. - Circle 2
E33. - Circle 3
E34. - Circle 4
E35. - Circle 5
E36. Quadrant 3 Circle 1
E37. - Circle 2
E38. - Circle 3
E39. - Circle 4
E40. - Circle 5
E41. Quadrant 4 Circle 1
E42. - Circle 2
E43. - Circle 3
E44. - Circle 4
E45. - Circle 5

It is easy to see from the above that considerable data was accumulated in the course of the experiment. Several elements in the Quadrant/Circle area had no symbols within them and were eliminated, this results in batches and sub-batches containing 37 elements for saturated secondary cells and 33 elements for the unsaturated secondary cells.

B. STATISTICAL ANALYSIS DESCRIPTION

Statistical Analysis was performed utilizing the Naval Postgraduate School Mainframe IBM 370/3033 Computer with an installed statistical programming package known as MINITAB. MINITAB was created in 1972 by the Pennsylvania State University for use by students in statistical analysis courses. It has since been expanded to allow use by anyone required to organize and analyze a large amounts of data. (Ryan, 1972, p. iii) MINITAB was utilized to perform four basic analytical functions:

1) Plotting of raw data
2) Calculation of percentages
3) Conducting a Two Sample T-Test
4) Conducting a One Way Analysis of Variance

The raw data was plotted merely to determine if any obvious trends were present and as a guideline towards further evaluation, the percentages were calculated for similar reasons (Example plots are in Appendix B). From these two initial evaluations, it was determined that the Two Sample T-Test and a One Way Analysis of Variance (AOV) would be the primary tools in analysis of the experiment.

1. **T-Test Analysis Technique**

The first major analysis was performed utilizing a TWO SAMPLE T-TEST. This test is designed to compare two independant samples using a Students T-Test and a 95% Confidence interval. The following equations are the basis of the T-Test:

$$(\bar{X}_1 - \bar{X}_2) - t\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}} \xrightarrow{\text{TO}} (\bar{X}_1 - \bar{X}_2) + t\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}$$

where:

$$t = \frac{(\bar{X}_1 - \bar{X}_2)}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}}$$

with degrees of freedom (df) equal to:

$$\left(\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}\right)^2 \Bigg/ \frac{\left(\frac{S_1^2}{n_1}\right)^2}{(n_1 - 1)} + \frac{\left(\frac{S_2^2}{n_2}\right)^2}{(n_2 - 1)}$$

This test is used to determine whether or not two samples have the same mean. The test prints out the means, standard deviations, standard error of the means, the 't' value and a 'p' value. The 'p' value is compared to a given alpha (in this case .05) based on the desired confidence level, if 'p' is less than alpha then the null hypothesis (equal means) is rejected. (Ryan, 1985, pp. 184-187) After the initial series of runs, it was discovered that the T-Test results corresponded exactly with the Analysis of Variance Results. From that point on, only the variance test was utilized.

2. **Analysis of Variance Technique**

The remaining analysis was done utilizing the One Way Analysis of Variance (AOV or ANOVA) feature of MINITAB. The null hypothesis for all comparisons was that there would be no change due the addition of color, any variation in target density, or in changing the time of exposure to each tactical display. In other words, all samples would have the same means if the null hypothesis were to hold true.

$$Ho = M_{\text{color}} = M_{\text{monochrome}}$$

or

$$H_o = M_{\text{10 seconds}} = M_{\text{60 seconds}}$$

or

$$H_o = M_{\text{saturated}} = M_{\text{unsaturated}}$$

To test these hypotheses with AOV, the following conditions had to hold true:

1) the sample had to be random
2) the population must have a normal distribution
3) the samples must have the same variance

Of these things, the most important requirement is that of randomness.

MINITAB output for AOV comes in two parts. The first part consists of tabulated data concerning the two populations under comparison, the second part describes the two sample populations (i.e., means, standard deviations, 95% Confidence Level (CL), and size). AOV calculates the sum of the squares,mean squares, degrees of freedom, and the F-Ratio. Of these, the degrees of freedom (DOF) and the F-Ratio are used to determine if the null hypotheses are true. The F-Ratio's and DOF's are used, together with the CL (.05 in this case), to enter the Statistical F-Distribution Table found in the CRC Standard Mathematical Tables (Beyer, 1984, p. 549). If the F-ratio calculated in MINITAB was greater than the tabulated value for the given DOF and CL, then the null hypothesis in question was rejected. (Appendix B has examples of AOV results for the Chunking Analysis).

The remainder of this chapter discusses the actual analysis of the data. The following sections concern time change analysis, density change analysis, color analysis, and chunking analysis. Each analytical section covers each Batch/Sub-Batch as a separate area. At the end of each area is a set of stand-alone conclusions concerning that area. (Appendix C consists of tables which show all the intercellular analysis results).

Chapter IV will discuss the possible causes and ramifications of the conclusions and trends noted in this chapter. Additionally, a final set of conclusions either supporting or not supporting the hypothesis of Chapter II will be given.

3. Definition of Terms

To aid in understanding the following analyses, the following terms should be understood:

BASIC FACTOR - The variable that is being changed in that particular analysis.

There are three BASIC FACTORS:

1) Time
2) Density
3) Color

BASIC RELATIONSHIP- The relationship between the number of correct responses and the basic factor.

EXTENDED FACTOR- The effect of color on a change in one of the remaining two factors (time or density).

EXTENDED RELATIONSHIP- The relationship between the number of correct responses and the extended factor.

SIGNIFICANT DIFFERENCE- Any difference which meets the AOV criteria established previously in this chapter.

C. TIME ANALYSIS

The basic time analysis null hypothesis was that changing the exposure time (time allowed for the subject to study the display) would have no effect on the subjects responses. In the extended null hypothesis time of exposure would not be effected by the addition of color to the displays.

$$H_{ot} : M_{10} = M_{60}$$

$$H_{xt} : x_{c} = x_{m}$$

c= color
m= monochrome
x= time factor

An analysis of variance test was run on all elements in the primary cells based on the secondary cells concerning time. The intracellular comparisons were: monochrome 10 second versus monochrome 60 second, and color 10 second versus color 60 second. The intercellular comparisons were; color 10 second versus monochrome 60 second and monochrome 10 second versus color 60 second. The density secondary cells were held constant throughout this set of comparisons. The intercellular results were qualitatively compared to the intracellular results. If a difference was found in both sets for comparative element samples, then that difference was assumed to be due to the basic factor (time). If the difference was not duplicated in the intracellular comparisons, then the difference was assumed to be due to the extended factor (presence or absence of color coding). A summary of the significant ANOVA results are shown in Tables 2 - 9. An overall summary of the percentages, showing the significant effect of time and those possibly associated with color are found in Table 10.

1. **Batch**

a. Unsaturated Displays

(1) *Intracell Comparisons.*

The monochrome test cell did not support the basic hypothesis. The results showed a 33% increase in correct results as the exposure time was increased from 10 seconds to 60 seconds. The color cell also failed to support the basic hypothesis. The color results indicated a 79% increase in correct results as the exposure time increased.

(2) *Intercell Comparisons.*

(1) Monochrome 60 Second vs Color 10 Second. When significant differences occured, the monochrome elements demonstrated 52% better results than the color elements. Only 6 of these elemental comparisons could be explained by the time differences. 33% of the differences could have been due to a lack of color coding in the display. This does not support the extended hypothesis and seems to indicate that a monochrome display may have a positive effect on subject performance.

(2) Monochrome 10 Second vs Color 60 Second. When a significant difference was noted, the color elements consistently showed improvement, in this case 55% over monochrome. All but 2 of these differences could be explained by the time factor. The addition of color seemed to improve performance by 6%.

TABLE 2

EXTREMES OF SIGNIFICANT ANOVA RESULTS
TIME ANALYSIS: INTRACELLULAR I

10 Second Unsaturated versus 60 Second Unsaturated
MONOCHROME

Batch

F-Ratio = 4.41

Upper Value

SOURCE	DF	SS	MS	F
FACTOR	1	72.20	72.20	18.05
ERROR	18	72.00	4.00	
TOTAL	19	144.20		

Lower Value

SOURCE	DF	SS	MS	F
FACTOR	1	9.80	9.80	5.80
ERROR	18	30.40	1.69	
TOTAL	19	40.20		

SubBatch 1

F-Ratio = 5.99

Only Value

SOURCE	DF	SS	MS	F
FACTOR	1	40.50	40.50	12.46
ERROR	6	19.50	3.25	
TOTAL	7	60.00		

SubBatch 2

F-Ratio = 4.96

Upper Value

SOURCE	DF	SS	MS	F
FACTOR	1	33.33	33.33	6.62
ERROR	10	50.33	5.03	
TOTAL	11	83.67		

Lower Value

SOURCE	DF	SS	MS	F
FACTOR	1	3.000	3.000	6.43
ERROR	10	4.667	0.467	
TOTAL	11	7.667		

TABLE 3

EXTREMES OF SIGNIFICANT ANOVA RESULTS
TIME ANALYSIS: INTRACELLULAR II

10 Second Saturated versus 60 Second Saturated
MONOCHROME

Batch

F-Ratio = 4.41

Upper Value

SOURCE	DF	SS	MS	F
FACTOR	1	259.2	259.2	19.79
ERROR	18	235.8	13.1	
TOTAL	19	495.0		

Lower Value

SOURCE	DF	SS	MS	F
FACTOR	1	33.80	33.80	4.93
ERROR	18	123.40	6.86	
TOTAL	19	157.20		

SubBatch 1

F-Ratio = 5.99

Only Value

SOURCE	DF	SS	MS	F
FACTOR	1	136.1	136.1	10.64
ERROR	6	76.7	12.8	
TOTAL	7	212.9		

SubBatch 2

F-Ratio = 4.96

Upper Value

SOURCE	DF	SS	MS	F
FACTOR	1	33.33	33.33	10.00
ERROR	10	33.33	3.33	
TOTAL	11	66.67		

Lower Value

SOURCE	DF	SS	MS	F
FACTOR	1	8.33	8.33	6.25
ERROR	10	13.33	1.33	
TOTAL	11	21.67		

TABLE 4

EXTREMES OF SIGNIFICANT ANOVA RESULTS
TIME ANALYSIS: INTRACELLULAR III

10 Second Unsaturated versus 60 Second Unsaturated
COLOR

Batch

F-Ratio = 4.41

Upper Value

SOURCE	DF	SS	MS	F
FACTOR	1	186.05	186.05	54.28
ERROR	18	61.70	3.43	
TOTAL	19	247.75		

Lower Value

SOURCE	DF	SS	MS	F
FACTOR	1	2.450	2.450	5.44
ERROR	18	8.100	0.450	
TOTAL	19	10.550		

SubBatch 1

F-Ratio = 5.99

Upper Value

SOURCE	DF	SS	MS	F
FACTOR	1	84.50	84.50	67.60
ERROR	6	7.50	1.25	
TOTAL	7	92.00		

Lower Value

SOURCE	DF	SS	MS	F
FACTOR	1	1.125	1.125	9.00
ERROR	6	0.750	0.125	
TOTAL	7	1.875		

SubBatch 2

F-Ratio = 4.96

Upper Value

SOURCE	DF	SS	MS	F
FACTOR	1	24.083	24.083	35.24
ERROR	10	6.833	0.683	
TOTAL	11	30.917		

Lower Value

SOURCE	DF	SS	MS	F
FACTOR	1	3.000	3.000	8.18
ERROR	10	3.667	0.367	
TOTAL	11	6.667		

TABLE 5

EXTREMES OF SIGNIFICANT ANOVA RESULTS
TIME ANALYSIS: INTRACELLULAR IV

10 Second Saturated VS 60 Second Saturated, COLOR

Batch

F-Ratio = 4.41

Upper Value

SOURCE	DF	SS	MS	F
FACTOR	1	101.25	101.25	26.15
ERROR	18	69.70	3.87	
TOTAL	19	170.95		

Lower Value

SOURCE	DF	SS	MS	F
FACTOR	1	5.000	5.000	5.23
ERROR	18	17.200	0.956	
TOTAL	19	22.200		

SubBatch 1

F-Ratio = 5.99

Upper Value

SOURCE	DF	SS	MS	F
FACTOR	1	12.500	12.500	21.43
ERROR	6	3.500	0.583	
TOTAL	7	16.000		

Lower Value

SOURCE	DF	SS	MS	F
FACTOR	1	36.12	36.12	9.53
ERROR	6	22.75	3.79	
TOTAL	7	58.87		

SubBatch 2

F-Ratio = 4.96

Upper Value

SOURCE	DF	SS	MS	F
FACTOR	1	48.00	48.00	12.74
ERROR	10	37.67	3.77	
TOTAL	11	85.67		

Lower Value

SOURCE	DF	SS	MS	F
FACTOR	1	14.08	14.08	5.00
ERROR	10	28.17	2.82	
TOTAL	11	42.25		

TABLE 6

EXTREMES OF SIGNIFICANT ANOVA RESULTS
TIME ANALYSIS: INTERCELLULAR I

Monochrome 10 versus Color 60

Batch unsaturated

F-Ratio value = 4.41
Upper Value

SOURCE	DF	SS	MS	F
FACTOR	1	145.80	145.80	42.33
ERROR	18	62.00	3.44	
TOTAL	19	207.80		

Lower Value

SOURCE	DF	SS	MS	F
FACTOR	1	5.00	5.00	4.69
ERROR	18	19.20	1.07	
TOTAL	19	24.20		

SubBatch 1 unsaturated

F-ratio value =5.99
Upper Value

SOURCE	DF	SS	MS	F
FACTOR	1	84.50	84.50	32.71
ERROR	6	15.50	2.58	
TOTAL	7	100.00		

Lower Value

SOURCE	DF	SS	MS	F
FACTOR	1	2.00	2.00	6.00
ERROR	6	2.00	0.33	
TOTAL	7	4.00		

SubBatch 2 unsaturated

F-ratio value =4.96
Upper Value

SOURCE	DF	SS	MS	F
FACTOR	1	18.75	18.75	30.41
ERROR	10	6.17	0.62	
TOTAL	11	24.92		

Lower Value

SOURCE	DF	SS	MS	F
FACTOR	1	2.08	2.08	5.00
ERROR	10	4.17	0.42	
TOTAL	11	6.25		

TABLE 7

EXTREMES OF SIGNIFICANT ANOVA RESULTS
TIME ANALYSIS: INTERCELLULAR II

Monochrome 10 versus Color 60

Batch saturated

F-Ratio value = 4.41

Upper Value

SOURCE	DF	SS	MS	F
FACTOR	1	540.80	540.80	28.55
ERROR	18	341.00	18.90	
TOTAL	19	881.80		

Lower Value

SOURCE	DF	SS	MS	F
FACTOR	1	6.05	6.05	4.84
ERROR	18	22.50	1.25	
TOTAL	19	28.55		

SubBatch 1 saturated

F-ratio value =5.99

Upper Value

SOURCE	DF	SS	MS	F
FACTOR	1	45.13	45.13	47.09
ERROR	6	5.75	0.96	
TOTAL	7	50.88		

Lower Value

SOURCE	DF	SS	MS	F
FACTOR	1	24.50	24.50	6.39
ERROR	6	23.00	3.83	
TOTAL	7	47.50		

SubBatch 2 saturated

F-ratio value =4.96

Upper Value

SOURCE	DF	SS	MS	F
FACTOR	1	70.08	70.08	22.73
ERROR	10	30.83	3.08	
TOTAL	11	100.92		

Lower Value

SOURCE	DF	SS	MS	F
FACTOR	1	5.33	5.33	5.71
ERROR	10	9.33	0.93	
TOTAL	11	14.66		

TABLE 8

EXTREMES OF SIGNIFICANT ANOVA RESULTS
TIME ANALYSIS: INTERCELLULAR III

Monochrome 60 versus Color 10

Batch unsaturated

F-Ratio value = 4.41

Upper Value

SOURCE	DF	SS	MS	F
FACTOR	1	101.25	101.25	25.42
ERROR	18	71.70	3.98	
TOTAL	19	172.95		

Lower Value

SOURCE	DF	SS	MS	F
FACTOR	1	8.45	8.45	4.46
ERROR	18	34.10	1.89	
TOTAL	19	42.55		

SubBatch 1 unsaturated

F-ratio value =5.99

Upper Value

SOURCE	DF	SS	MS	F
FACTOR	1	18.00	18.00	27.00
ERROR	6	4.00	0.67	
TOTAL	7	22.00		

Lower Value

SOURCE	DF	SS	MS	F
FACTOR	1	6.13	6.13	6.39
ERROR	6	5.75	0.96	
TOTAL	7	11.88		

SubBatch 2 unsaturated

F-ratio value =4.96

Upper Value

SOURCE	DF	SS	MS	F
FACTOR	1	102.10	102.10	8.18
ERROR	10	124.80	12.50	
TOTAL	11	226.90		

Lower Value

SOURCE	DF	SS	MS	F
FACTOR	1	21.33	21.33	8.00
ERROR	10	26.67	2.67	
TOTAL	11	48.00		

TABLE 9

EXTREMES OF SIGNIFICANT ANOVA RESULTS
TIME ANALYSIS: INTERCELLULAR IV

Monochrome 60 versus Color 10

Batch saturated

F-Ratio value = 4.41
Upper Value

SOURCE	DF	SS	MS	F
FACTOR	1	186.00	186.00	11.67
ERROR	18	286.90	15.90	
TOTAL	19	472.90		

Lower Value

SOURCE	DF	SS	MS	F
FACTOR	1	9.80	9.80	5.04
ERROR	18	35.00	1.94	
TOTAL	19	44.80		

SubBatch 1 saturated

F-ratio value =5.99
Upper Value

SOURCE	DF	SS	MS	F
FACTOR	1	8.00	8.00	24.00
ERROR	6	2.00	0.33	
TOTAL	7	10.00		

Lower Value

SOURCE	DF	SS	MS	F
FACTOR	1	10.12	10.12	7.84
ERROR	6	7.75	1.29	
TOTAL	7	17.87		

SubBatch 2 saturated

F-ratio value =4.96
Upper Value

SOURCE	DF	SS	MS	F
FACTOR	1	102.10	102.10	8.18
ERROR	10	124.80	12.50	
TOTAL	11	226.90		

Lower Value

SOURCE	DF	SS	MS	F
FACTOR	1	21.33	21.33	8.00
ERROR	10	26.67	2.67	
TOTAL	11	48.00		

TABLE 10

SUMMARY OF TIME ANALYSIS IMPROVEMENTS

	Batch	SubBatch 1	SubBatch 2
Intracell			
Unsaturated			
M60 vs M10	33.0	3.0	6.0
C60 vs C10	79.0	30.0	27.0
Saturated			
M60 vs M10	46.0	8.0	11.0
C60 vs M10	49.0	19.0	22.0
Intercell			
Unsaturated			
M60 vs C10	33.0	12.0	15.0
C60 vs M10	6.0	18.0	6.0
Saturated			
M60 vs C10	8.0	8.0	5.0
C60 vs M10	24.0	30.0	30.0

ALL PERCENTAGES INDICATE IMPROVEMENT AT 60 SECONDS.

Percentage calculations: $\frac{\text{total number of differences}}{\text{total comparisons}}$

M = monochrome C = color
10 = 10 seconds 60 = 60 seconds

b. Saturated Displays

(1) *Intracell Comparisons.*

The monochrome cell did not support the basic null hypothesis. The results indicated a 46% improvement with increased exposure time. The color cell also failed to support the null hypothesis. These results showed a 49% improvement with increased exposure time.

(2) *Intercell Comparisons.*

(1) Monochrome 60 Seconds vs Color 10 Seconds. As in the unsaturated case, the monochrome elements showed an improvement over the color elements (38%). All but three of these results could be explained by increased exposure times for the basic factor. The lack of color seems to have had a positive effect in the remaining three cases (8%).

(2) Monochrome 10 Seconds vs Color 60 Seconds. Again, the color elements showed an improvement over the monochrome elements, this time in 70% of the sample cases. All but 9 elements could be explained by the increased exposure time. In this case, it appears that the addition of color had a positive effect on performance in 24% of the cases.

2. **SubBatch 1**

a. Unsaturated

(1) *Intracell Comparison.*

The monochrome cell showed only a 3% improvement with time, this tends to support the basic hypothesis. The color cell showed a 30% improvement with time, this leads to a rejection of the basic hypothesis.

(2) *Intercell Comparison.*

(1) Monochrome 60 Seconds vs Color 10 Seconds. The monochrome elements showed a 15% improvement over the same elements in the color cell. Only one element was attributable to the increase in the time factor. The lack of color seemed to have a positive effect in 12% of the test cases.

(2) Monochrome 10 Second vs Color 60 Seconds. The color elements showed a 33% improvement over the monochrome elements. Of these differences, 45% could be attributed to the increase in the basic factor. The addition of color seemed to have a positive effect on performance in 18% of the sample cases.

b. *Saturated Displays*

(1) *Intracell Comparisons.*

The monochrome cell showed an 8% improvement with increased time. The color cell showed a 19% improvement with time.

(2) *Intercell Comparisons.*

(1) Monochrome 60 Seconds vs Color 10 Seconds. The monochrome elements showed an 8% improvement over the color elements. None of the differences were attributable to the basic factor. The lack of color seems to have been beneficial in 8% of the test cases.

(2) Monochrome 10 Seconds vs. Color 60 Seconds. The color elements showed a 43% improvement over the monochrome elements. Only 32% of the noted differences could be explained by the time factor. The addition of color seems to have had a positive effecting 30% of the cases.

3. SubBatch 2

a. *Unsaturated Displays*

(1) *Intracell Comparison.*

The monochrome cell showed a 6% improvement with time. The color cell showed a 27% improvement with time.

(2) *Intercell Comparison.*

(1) Monochrome 60 Seconds vs Color 10 Seconds. The monochrome elements showed a 18% improvement over the same elements in the color cell. Only 1 element was attributable to the increase in the time factor. The lack of color seemed to have been beneficial in 15% of the cases.

(2) Monochrome 10 Seconds vs Color 60 Seconds. The color elements showed a 21% improvement over the monochrome elements. Of these differences, all but 2 were caused by the increase in the basic factor. The addition of color seemed to have a positive effect on performance in 6% of the sample cases.

b. *Saturated Displays*

(1) *Intracell Comparison.*

The monochrome cell showed an 11% improvement with increased time. The color cell showed a 22% improvement with time.

(2) *Intercell Comparison.*

(1) Monochrome 60 Seconds vs Color 10 Seconds. The monochrome elements showed a 5% improvement over the color elements. None of the differences

were attributable to the basic factor. The lack of color seems to have been beneficial in all the test cases.

(2) Monochrome 10 Seconds vs Color 60 Seconds. The color elements showed a 46% improvement over the monochrome elements. Only 34% of the noted differences could be explained by the time factor. The addition of color seems to have had a positive effect on 30% of the cases.

4. **Initial Conclusions Concerning Exposure Time**

1) The basic null hypothesis seems to be invalid in all but 1 case; in SubBatch 1 the unsaturated monochrome display results indicated only a 3% improvement.

2) The extended time hypothesis also seems to be invalid.

a) For the UNSATURATED cases, the monochrome display effected the over all results more significantly than in the color displays (33% vs 6%). SubBatch 2 demonstrated this trend to a lesser degree (15% vs 6%). In Sub Batch 1, those familiar with NTDS, the opposite trend was indicated, that is color had more effect than monochrome in 18% of the cases versus 12%.

b) When the displays were SATURATED the color coding affected all the results to a greater degree than monochrome feature did, regardless of exposure time.

3) There was little evidence that the addition of color aided one SubBatch more than it did the other. Research results by other experimenters indicated that color would help those unfamiliar with the symbology more than it would help those familiar with the system. (Teichner, 1977, p. 17)

D. DENSITY ANALYSIS

The basic null hypothesis was that the number of correct responses would not be effected by the number of symbols in the display. The extended null hypothesis concerning density was that color coding would have no effect on these results.

To determine the validity of this hypothesis, a total of 8 AOV tests were done , 4 for each time. One run compared within the monochrome cell, another within the color cell, and the final two between cells. As with the time analysis, the same tests were repeated for the batch and the two subbatches. The specific tests were set up as follows:

1) Monochrome Unsaturated vs Monochrome Saturated

2) Color Unsaturated vs Color Saturated

3) Monochrome Unsaturated vs Color Saturated

4) Color Unsaturated vs Monochrome Saturated

The AOV tests compared the first 20 elements of each cell, this covers the first four groups, type, group, type & group, and quadrant. A summary of significant ANOVA results are in Tables 11 - 18. A summary of the percentages is in Table 19.

1. **Batch**

a. 10 Seconds

(1) *Intracell Comparisons.*

At least 90% of all the elements supported the null hypothesis (95% in the monochrome case). When any significant differences were noted, the saturated displays always had the higher percentages of correct responses.

(2) *Intercell Comparisons.*

(1) Monochrome Unsaturated vs Color Saturated. No differences were noted, the extended hypothesis seems to be valid.

(2) Monochrome Saturated vs Color Unsaturated. 3 differences were noted, only one of which was explainable by reference to intracell results. In the remaining cases, the monochrome displays had 'better' results. The specific elements were Surface Type and Quadrant 2 responses.

b. 60 Seconds

(1) *Intracell Comparisons.*

55% of the color elements and 70% of the monochrome ones supported the null hypothesis. In both cases, the total number of correct responses was significantly better for the saturated displays. This tends to support the alternate hypothesis that the means between the two population samples were not equal, and specifically, that relatively 'better' responses occur with the saturated displays.

(2) *Intercell Comparisons.*

(1) Monochrome Unsaturated vs Color Saturated. Only 1 difference was found and it could be explained by the basic relationship.

(2) Monochrome Saturated vs Color Unsaturated. 9 differences were found, with all but 3 being attributable to the basic relationship. For the remaining 3, the friendly contacts, hostile surface, and quadrant 1 elements were significantly 'better' in the saturated color displays.

TABLE 11

EXTREMES OF SIGNIFICANT ANOVA RESULTS
DENSITY ANALYSIS: INTRACELLULAR I

10 Second Saturated vs 10 Second Unsaturated
MONOCHROME

BATCH

F-Ratio = 4.41

Only Value

SOURCE	DF	SS	MS	F
FACTOR	1	8.45	8.45	6.76
ERROR	18	22.50	1.25	
TOTAL	19	30.95		

SubBatch 1

F-Ratio = 5.99

Upper Value

SOURCE	DF	SS	MS	F
FACTOR	1	8.00	8.00	8.00
ERROR	6	6.00	1.00	
TOTAL	11	14.00		

Lower Value

SOURCE	DF	SS	MS	F
FACTOR	1	6.125	6.125	6.39
ERROR	6	5.750	0.958	
TOTAL	11	11.875		

SubBatch 2

F-Ratio = 4.96

Upper Value

SOURCE	DF	SS	MS	F
FACTOR	1	2.083	2.083	7.35
ERROR	10	2.833	0.283	
TOTAL	11	4.917		

Lower Value

SOURCE	DF	SS	MS	F
FACTOR	1	0.750	0.750	5.00
ERROR	10	1.500	0.150	
TOTAL	11	2.250		

TABLE 12

EXTREMES OF SIGNIFICANT ANOVA RESULTS
DENSITY ANALYSIS: INTRACELLULAR II

60 Second Saturated vs 60 Second Unsaturated
MONOCHROME

Batch

F-Ratio = 4.41

Upper Value

SOURCE	DF	SS	MS	F
FACTOR	1	18.05	18.05	17.56
ERROR	18	18.50	1.03	
TOTAL	19	36.55		

Lower Value

SOURCE	DF	SS	MS	F
FACTOR	1	76.00	76.00	6.69
ERROR	18	204.50	11.40	
TOTAL	19	280.50		

SubBatch 1

F-Ratio = 5.99

Upper Value

SOURCE	DF	SS	MS	F
FACTOR	1	12.50	12.50	25.00
ERROR	6	3.00	0.50	
TOTAL	11	15.50		

Lower Value

SOURCE	DF	SS	MS	F
FACTOR	1	21.12	21.12	7.57
ERROR	6	16.75	2.79	
TOTAL	11	37.87		

SubBatch 2

NO SIGNIFICANT DIFFERENCES NOTED

TABLE 13

EXTREMES OF SIGNIFICANT ANOVA RESULTS
DENSITY ANALYSIS: INTRACELLULAR III

10 Second Saturated versus 10 Second Unsaturated
MONOCHROME

Batch

NO SIGNIFICANT DIFFERENCES NOTED

SubBatch 1

F-ratio value = 5.99

Only Value

SOURCE	DF	SS	MS	F
FACTOR	1	21.12	21.12	18.78
ERROR	6	6.75	1.12	
TOTAL	11	27.87		

SubBatch 2

F-ratio value = 4.96

Only Value

SOURCE	DF	SS	MS	F
FACTOR	1	14.08	14.08	7.48
ERROR	10	18.837	1.88	
TOTAL	11	32.92		

TABLE 14

EXTREMES OF SIGNIFICANT ANOVA RESULTS DENSITY ANALYSIS: INTRACELLULAR IV

60 Second Saturated versus 60 Second Unsaturated
COLOR

Batch

F-ratio value = 4.41
Upper Value

SOURCE	DF	SS	MS	F
FACTOR	1	6.05	6.05	6.44
ERROR	18	16.90	0.939	
TOTAL	19	22.95		

Lower Value

SOURCE	DF	SS	MS	F
FACTOR	1	24.20	24.20	34.57
ERROR	18	12.60	0.70	
TOTAL	19	36.80		

SubBatch 1

F-ratio value = 5.99
Upper Value

SOURCE	DF	SS	MS	F
FACTOR	1	8.00	8.00	13.71
ERROR	6	3.50	0.58	
TOTAL	11	11.50		

Lower Value

SOURCE	DF	SS	MS	F
FACTOR	1	6.125	6.125	7.74
ERROR	6	4.750	0.792	
TOTAL	11	10.875		

SubBatch 2

F-ratio value = 4.96
Upper Value

SOURCE	DF	SS	MS	F
FACTOR	1	16.333	16.333	24.50
ERROR	10	6.667	0.667	
TOTAL	11	23.000		

Lower Value

SOURCE	DF	SS	MS	F
FACTOR	1.	5.333	5.333	11.43
ERROR	10	4.667	0.467	
TOTAL	11	10.000		

TABLE 15

EXTREMES OF SIGNIFICANT ANOVA RESULTS
DENSITY ANALYSIS: INTERCELLULAR I

Monochrome 10U versus Color 10S

Batch

NO SIGNIFICANT DIFFERENCES NOTED

SubBatch 1

NO SIGNIFICANT DIFFERENCES NOTED

SubBatch 2

F-ratio value = 4.96

Only Value

SOURCE	DF	SS	MS	F
FACTOR	1	3.00	3.00	7.50
ERROR	10	4.00	0.40	
TOTAL	11	7.00		

TABLE 16

EXTREMES OF SIGNIFICANT ANOVA RESULTS
DENSITY ANALYSIS: INTERCELLULAR II

Monochrome 10S versus Color 10U

Batch

F-Ratio value = 4.41

Upper Value

SOURCE	DF	SS	MS	F
FACTOR	1	12.80	12.80	11.52
ERROR	18	20.00	1.11	
TOTAL	19	32.80		

Lower Value

SOURCE	DF	SS	MS	F
FACTOR	1	11.25	11.25	6.01
ERROR	18	33.70	1.87	
TOTAL	19	44.95		

SubBatch1

F-ratio value =5.99

Upper Value

SOURCE	DF	SS	MS	F
FACTOR	1	15.12	15.12	13.44
ERROR	6	6.75	1.12	
TOTAL	7	21.87		

Lower Value

SOURCE	DF	SS	MS	F
FACTOR	1	6.13	6.13	6.39
ERROR	6	5.75	0.96	
TOTAL	7	11.88		

SubBatch2

F-ratio value = 4.96

Only Value

SOURCE	DF	SS	MS	F
FACTOR	1	6.75	6.75	5.00
ERROR	10	13.50	1.35	
TOTAL	11	20.25		

TABLE 17

EXTREMES OF SIGNIFICANT ANOVA RESULTS
DENSITY ANALYSIS: INTERCELLULAR III

Monochrome 60U versus Color 60S

Batch

F-Ratio value = 4.41

Upper Value

SOURCE	DF	SS	MS	F
FACTOR	1	26.45	26.45	47.14
ERROR	18	10.10	0.56	
TOTAL	19	36.55		

Lower Value

SOURCE	DF	SS	MS	F
FACTOR	1	16.20	16.20	5.03
ERROR	18	58.00	3.22	
TOTAL	19	74.20		

SubBatch 1

NO SIGNIFICANT DIFFERENCES NOTED

SubBatch 2

F-ratio value = 4.96

Upper Value

SOURCE	DF	SS	MS	F
FACTOR	1	16.33	16.33	35.00
ERROR	10	4.67	0.47	
TOTAL	11	21.00		

Lower Value

SOURCE	DF	SS	MS	F
FACTOR	1	4.08	4.08	5.00
ERROR	10	8.17	0.82	
TOTAL	11	12.25		

TABLE 18

EXTREMES OF SIGNIFICANT ANOVA RESULTS
DENSITY ANALYSIS: INTERCELLULAR IV

Monochrome 60S versus Color 60U

Batch

F-Ratio value = 4.41

Upper Value

SOURCE	DF	SS	MS	F
FACTOR	1	16.20	16.20	13.89
ERROR	18	21.00	1.17	
TOTAL	19	37.20		

Lower Value

SOURCE	DF	SS	MS	F
FACTOR	1	5.00	5.00	4.79
ERROR	18	18.80	1.04	
TOTAL	19	23.80		

SubBatch1

F-ratio value =5.99

Upper Value

SOURCE	DF	SS	MS	F
FACTOR	1	28.13	28.13	29.35
ERROR	6	5.75	0.96	
TOTAL	7	33.88		

Lower Value

SOURCE	DF	SS	MS	F
FACTOR	1	32.00	32.00	6.98
ERROR	6	27.50	4.58	
TOTAL	7	59.50		

SubBatch2

F-ratio value = 4.96

Upper Value

SOURCE	DF	SS	MS	F
FACTOR	1	14.08	14.08	5.83
ERROR	10	24.17	2.42	
TOTAL	11	38.25		

Lower Value

SOURCE	DF	SS	MS	F
FACTOR	1	2.08	2.08	5.00
ERROR	10	4.17	0.42	
TOTAL	11	6.25		

TABLE 19

SUMMARY OF DENSITY ANALYSIS IMPROVEMENTS

		Batch	SubBatch 1	SubBatch 2
Intracell				
10 seconds				
MU vs MS		5.0	10.0	15.0*
CU vs CS		10.0	5.0	10.0
60 seconds				
MU vs MS		30.0	20.0	0.0
CU vs CS		45.0	45.0	30.0
Intercell				
10 seconds				
MU vs CS				
Monochrome	US	0.0	0.0	5.0
Color	S	0.0	0.0	0.0
MS vs CU				
Monochrome	S	10.0	5.0	5.0
Color	US	0.0	0.0	0.0
60 seconds				
MU vs CS				
Monochrome	US	15.0	0.0	0.0
Color	S	0.0	5.0	25.0
MS vs CU				
Monochrome	S	10.0	0.0	10.0
Color	US	10.0	0.0	5.0

Percentage calculation: $\dfrac{\text{total number of differences}}{\text{total comparisons}}$

* Unsaturated display showed improvement. All other INTRACELL results indicated saturated display was better.

M = monochrome C = color
U = unsaturated S = saturated

2. **SubBatch 1**

a. 10 Seconds

(1) *Intracell Comparisons.*

90% or more of all the elements supported the null hypothesis (95% in the color case). As with the Batch results, the saturated displays always had the higher percentages of correct responses.

(2) *Intercell Comparisons.*

(1) Monochrome Unsaturated vs Color Saturated. No differences were noted, the extended hypothesis seems to be valid.

(2) Monochrome Saturated vs Color Unsaturated. 3 differences were found, all but 1 of these were explained by the basic relationship. The remaining difference was in Q2.

b. 60 Seconds Exposure Times

(1) *Intracell Comparisons.*

As with the batch results,55% of the color elements supported the null hypothesis. 80% of the monochrome elements showed no difference. In both cells the saturated display was 'better' than the unsaturated one.

(2) *Intercell Comparisons.*

(1) Monochrome Unsaturated vs Color Saturated. 8 differences were found, with all but 1 being attributable to the basic relationship. The hostile element was 'better' in the color displays.

(2) Monochrome Saturated vs Color Unsaturated. Only three differences were found, all explainable by the basic relationship.

3. **SubBatch 2**

a. 10 Seconds

(1) *Intracell Comparison.*

85% or more of all the elements supported the null hypothesis (90% in the color case). The saturated displays had the higher percentages of correct responses in all but 3 cases. In the monochrome cell the elements submarine, neutral, and neutral air were all better in the unsaturated displays.

(2) *Intercell Comparison.*

(1) Monochrome Unsaturated vs Color Saturated. 1 difference was noted and unexplainable by the basic relationship. The element Q1 was better in the monochrome displays.

(2) Monochrome Saturated vs Color Unsaturated. 1 difference was noted and unexplainable by the basic relationship. The element neutral surface was better in the monochrome displays.

b. 60 Seconds

(1) *Intracell Comparisons.*

70% of the color elements and 100% of the monochrome supported the null hypothesis. 80% of the monochrome elements showed no difference. In both cells the saturated display was 'better' than the unsaturated one.

(2) *Intercell Comparison.*

(1) Monochrome Unsaturated vs Color Saturated. 9 differences were found, with all but 5 being attributable to the basic relationship. The elements for total response, air, neutral, friendly air, and hostile surface all indicated better color results.

(2) Monochrome Saturated vs Color Unsaturated. Three differences were found, none explainable by the basic relationship The elements for surface and neutral were better in monochrome, but the element for Q1 was better in the color display.

4. Initial Conclusions from the Density Analysis

1) At the 10 second viewing time,the density null hypothesis holds valid. There does appear to be a slight tendency for saturated displays to be better.

2) At 60 second exposure times, the density null hypothesis appears to be false with regards to the Batch and to Sub Batch 1, the alternative hypothesis indicating that the populations are different seems to hold (favoring the saturated populations as being better). Sub Batch 2 supports the null hypothesis in the monochrome cell, but agrees with the previous alternate in the color cell.

3) At 10 seconds, the extended null hypothesis also seems to be valid with a very slight tendency towards monochrome displays being preferred.

4) At 60 seconds, the extended null hypothesis seems to be valid for the Batch and for Sub Batch 1. However, the color display seems to have some positive effect on the responses of Sub Batch 2, the Unfamiliar population.

E. COLOR ANALYSIS

The color null hypothesis stated that the addition of color would have no effect on the number of correct responses. The alternate hypothesis stated that the addition of color will effect the number of correct responses.

$$H_{oc} : M_c = M_m$$

$$H_1 : M_c = M_m$$

An initial comparison was done using an AOV test on the two primary cells, while holding all other factors constant (i.e., monochrome 60sec saturated versus color 60 sec saturated). The results of this comparison should show the effect of the basic factor (color). Following this analysis three more qualitative comparisons were conducted. These additional comparisons tried to determine whether a synergistic effect occurred -- i.e., two or more of the factors combined and caused an improvement to be noted.

First, the significant results of the color factor tests were qualitatively compared to those significant results which could not be accounted for by the time factor. From this comparison, two outcomes were possible: one, the color factor alone could explain the result or two, the result was due to both factors.

Second, the significant results of the color factor tests were qualitatively compared to those significant results which could not be accounted for by the density factor. As noted above, there were two possible outcomes, one, the color factor alone could explain the result or two, the result was due to both factors.

The last comparison used the significant results of all three factors. Any difference which was found to be the result of the dual effect of color and time as well as the dual effect of color and density was determined to have had a triple interaction of the three factors (i.e., a total synergistic effect).

For example, in Appendix C, Tables 26, 27, and 36 were qualitatively compared, with the results shown in Table 37.

A summary of the significant ANOVA results are in Tables 20 - 22. Table 23 shows the percentages in terms of the pooled secondary cells (i.e., 140 comparisons).

1. **Batch**

a. Color

In only 4.3% of the comparisons were there significant differences between the color cell and the monochrome cell. In all these cases, the color cell showed better results.

b. Color plus time

None of the results from these comparisons could be related solely to the effect of color. Of the dual effects, 7.1% showed improvements with color and time. However, 9.3% showed improvement with monochrome and time.

TABLE 20

EXTREMES OF SIGNIFICANT ANOVA RESULTS
COLOR ANALYSIS: INTERCELLULAR I

Monochrome 10 versus Color 10, unsaturated

Batch

NO SIGNIFICANT DIFFERENCES NOTED

SubBatch 1

NO SIGNIFICANT DIFFERENCES NOTED

SubBatch 2

F-ratio value = 4.96

Only Value

SOURCE	DF	SS	MS	F
FACTOR	1	3.00	3.00	5.29
ERROR	10	5.67	0.57	
TOTAL	11	8.67		

TABLE 21

EXTREMES OF SIGNIFICANT ANOVA RESULTS
COLOR ANALYSIS: INTERCELLULAR II

Monochrome 10 versus Color 10, saturated
Batch

F-Ratio value = 4.41

Only Value

SOURCE	DF	SS	MS	F
FACTOR	1	6.05	6.05	5.53
ERROR	18	19.70	1.09	
TOTAL	19	25.75		

SubBatch 1

F-ratio value = 5.99

Upper Value

SOURCE	DF	SS	MS	F
FACTOR	1	21.12	21.12	9.94
ERROR	6	12.75	2.12	
TOTAL	7	33.87		

Lower Value

SOURCE	DF	SS	MS	F
FACTOR	1	8.00	8.00	6.00
ERROR	6	8.00	1.33	
TOTAL	7	16.00		

SubBatch 2

NO SIGNIFICANT DIFFERENCES NOTED

TABLE 22

EXTREMES OF SIGNIFICANT ANOVA RESULTS
COLOR ANALYSIS: INTERCELLULAR III

Monochrome 60 versus Color 60, unsaturated

Batch

F-Ratio value = 4.41

Upper Value

SOURCE	DF	SS	MS	F
FACTOR	1	9.80	9.80	11.61
ERROR	18	341.00	18.90	
TOTAL	19	881.80		

Lower Value

SOURCE	DF	SS	MS	F
FACTOR	1	9.80	9.80	5.04
ERROR	18	35.00	1.94	
TOTAL	19	44.80		

SubBatch 1

NO SIGNIFICANT DIFFERENCES NOTED.

SubBatch 2

F-ratio value = 4.96

Upper Value

SOURCE	DF	SS	MS	F
FACTOR	1	12.00	12.00	18.00
ERROR	10	6.67	0.67	
TOTAL	11	18.67		

Lower Value

SOURCE	DF	SS	MS	F
FACTOR	1	2.08	2.08	5.00
ERROR	10	4.17	0.42	
TOTAL	11	6.25		

TABLE 23

SUMMARY OF COLOR IMPROVEMENTS

	Batch	SubBatch 1	SubBatch 2
Pure Color	4.3	1.4	4.3
	0.0	0.0	0.0
Color plus time	7.1	12.0	9.3
	9.3	5.0	5.0
Color plus density	2.0	0.0	3.6
	3.0	0.7	2.9
Color plus time plus density	0.7	0.7	0.0
	0.0	0.0	0.0
Total effects			
Color	14.1	14.1	17.2
Monochrome	9.3	5.0	7.9
Total	23.4	19.1	25.1

Percentage calculation: $\frac{\text{total number of differences}}{\text{total comparisons}}$

Upper number indicates improvement in multicolor over monochrome.
Lower number indicates improvement in monochrome over multicolor.

c. Color plus density

One of the results from these comparisons could be related to the effect of color. Of the dual effects, 2% showed improvements with color and density; 3% showed improvement with monochrome and density.

d. Color plus time plus density

Only one result (.7%) seemed to indicate a triple interaction; this result was for 60s, saturated, hostile surface.

2. **SubBatch 1**

a. Color

In only 1.4% of the comparisons were there significant differences between the color cell and the monochrome cell. In both these cases, color cell showed better results.

b. Color plus time

None of the results from this comparison could be related solely to color effect. Of the dual effects, 12% showed improvement due to color and time. 5% showed improvement due to monochrome and time combination.

c. Color plus density

None of the results from this comparison could be related solely to the color effect. The only dual effect noted was for the monochrome/density combination: .7%.

d. Color plus time plus density

The triple interaction occurred only once (.7%) with color, 60 sec, saturated hostiles showing the improvement over the monochrome cell.

3. **SubBatch 2**

a. Color

There were significant differences in only 4.3% of the comparisons. In all cases, the color cell showed better results.

b. Color plus time

As in the other two analysis (Batch and Subbatch 1), none of the results could be explained by the basic factor of color. Of the dual effects, 9.3% showed improvement in the color/time combination. 5% showed improvement in the monochrome/time combination.

c. Color plus density

Only one result could be explained by the basic factor of color. Of the dual effect, 3.6% showed improvement with the color and density combination. 2.9% showed improvement with the monochrome/density combination.

d. Color plus time plus density

No triple interaction was noted.

4. **Initial Color Conclusions**

1) The color null hypothesis seems to be valid when the effect of color is analyzed in a static sense, relative to the two other basic factors of time and density.
2) The color null hypothesis seems to be invalid when the dual effect of color and time is analyzed.
3) The color null hypothesis seems to be valid when the dual effect of color and density is analyzed.
4) The color null hypothesis seems to be valid when the possibility of triple interaction is analyzed.
5) Overall, when these results are combined, looking for any type of effect of changing the display type (monochrome or color), 19 to 25 percent of the results showed an effect. This percentage would tend to disprove the color null hypothesis.
6) The color displays seem to have a greater positive effect (14.1%-17.2%) on the number of correct responses than did the monochrome displays (5%-9.3%). This fact is shown very clearly in both subbatches.

F. CHUNKING ANALYSIS

As discussed in Chapter I, chunking involves the mental grouping of symbols based on some type of relationship which allows the user to, theoretically, recall information faster and with greater accuracy. The basic chunking null hypothesis was that there would be no significant difference between the number of correct responses for a given element of a group and other elements within that group. The extended chunking null hypothesis (xch) was that the addition of color would not affect chunking if the basic hypothesis was wrong.

$$H_{och} : M_c = M_m$$

$$H_{xch} : x_c = x_m \qquad x = \text{chunking changes}$$

c = color

m = monochrome

This analysis extended only through the first 4 groups. Each element, with the exception of the quadrant elements, was compared to its associated elements in the group, using an AOV test. The quadrant elements were compared using percentages, due to the differing numbers of symbols in each quadrant. If an element was found to be significantly different from all other group elements, this could show that it had been selectively chosen or ignored. If the element differed from 2 or more elements, but not from all, then partial selection could have been in effect. For example, if Quadrant 1 (E17) was significantly different from Quadrant 2 (E18), Quadrant 3 (E19) and Quadrant 4 (E20), then complete selection (for or against) occurred. If Quadrant 1 differed only from Quadrants 2 and 3, then partial selection (for or against) occurred. These comparisons were made within each primary cell and then a qualitative comparison was made between the primary cells. In addition, the results were compared to the information provided by each subject on the questionnaire. The questionnaire results are shown in Table 24. The cell comparison results are shown in Figure 3.3.

1. **Batch**

a. 10 seconds

(1) *Color.*

(1) Type. No evidence of chunking.

(2) Threat. In the saturated display, there was one instance of complete selection against the friendly element.

(3) Type and Threat. No evidence of chunking.

(4) Quadrants. In the unsaturated display, partial selection occurred for Quadrants 1 and 4.

In the saturated display, partial selection occurred for Quadrants 2 and 3.

(2) *Monochrome.*

(1) Type. No evidence of chunking.

(2) Threat. No evidence of chunking.

(3) Type and Threat. No evidence of chunking.

(4) Quadrants. In the unsaturated display, there was one instance of complete selection for Quadrant 2. There was also partial selection against Quadrants 1 and 4.

TABLE 24

SUMMARY OF CHUNKING RESULTS
BASED ON QUESTIONNAIRES

Method	Cell 1	Cell 2
Pure Quadrant	0	3
Pure Threat	1	0
Quadrants plus type	1	4
Quadrants plus threat	5	1
Quadrants plus pattern	0	1
Variable	4	0

Cell 1 = Primary cell, Color, Batch

Cell 2 = Primary cell, Monochrome, Batch

pattern = geometric pattern between two or more elements

variable = method changed throughout experiment Quadrants, Threat, Type, Patterns

Reconstruction phase was dominated by quadrants.

	C 10 US			M 10 US			C 10 S			M 10 S			C 60 US			M 60 US			C 60 S			M 60 S		
	A	F	N	A	F	N	A	F	N	A	F	N	A	F	N	A	F	N	A	F	N	A	F	N
tot																								
air																								
surf									S	S	S								S		S	S		S
sub																								
fri																								
hos	F						F	F	F N							F		F						
neu								F		F								F			F	F	F	
Q 1	3 2	4 3 2	3 2		4			3		3	4		2		4 3 2								3	
Q 2		3		4 3 1	4 1	4 3 1	4 1	4 3 1	4 1	4 3 1	4 3 1	4 3 1		1	4	1		1	4 3 1	3	4 3 1	3 1	4 3 1	1
Q 3				4 1	4 1		4 1		4 1				2	1 2	4 2	4 2 1	4 2 1	4 2 1	1		1	1		1
Q 4	3 2	3 2	3 2			1		3					2	3 2 1		2 1		2 1	3 1	3 1	3 1	3	3 1	1

C = COLOR M = MONOCHROME
US = UNSATURATED S = SATURATED
10 = 10 SECONDS 60 = 60 SECONDS
A = Batch F = SubBatch 1 N = SubBatch 2

The letters and numbers indicated those elements that were selected against.
F= Friendly S = Submarine N = Neutral
1 = Quad 1 2 = Quad 2 3 = Quad 3 4 = Quad 4

Figure 3.3 Chunking Results.

In the saturated display, there was complete selection for Quadrant 2. There was also partial selection against Quadrant 3.

(3) *Intercellular.* In the saturated displays, the friendly elements were selected against in the color view. No effect was noted in the monochrome displays.

b. 60 seconds

(1) *Color.*

(1) Type. No evidence of chunking.

(2) Threat. No evidence of chunking.

(3) Type and Threat. No evidence of chunking.

(4) Quadrants. In the unsaturated display, there was complete selection against Quadrant 2.

In the saturated display, there was complete selection against Quadrant 1 and for Quadrant 2.

(2) *Monochrome.*

(1) Type. No evidence of chunking.

(2) Threat. No evidence of chunking.

(3) Type and Threat. No evidence of chunking.

(4) Quadrants. In the unsaturated display, there was complete selection for Quadrant 3 and against Quadrant 1. Partial selection occurred against Quadrant 2.

In the saturated display, there was partial selection against Quadrant 1 and 3.

(3) *Intercellular.* No significant differences.

2. **SubBatch 1**

a. 10 seconds

(1) *Color.*

(1) Type. No evidence of chunking.

(2) Threat. In the saturated display, there was complete selection for the hostile element.

(3) Type and Threat. No evidence of chunking.

(4) Quadrants. In the unsaturated display, there was complete selection for Quadrant 1 and against Quadrant 3. There was also partial selection against Quadrant 2.

In the saturated display, there was complete selection for Quadrant 2 and against Quadrant 3.

(2) *Monochrome.*

(1) Type. No evidence of chunking.

(2) Threat. No evidence of chunking.

(3) Type and Threat. No evidence of chunking.

(4) Quadrants. In the unsaturated display, there was complete selection against Quadrant 4. There was also partial selection against Quadrant 1.

In the saturated display, there was complete selection for Quadrant 2. Partial selection occurred against Quadrants 3 and 4.

(3) *Intercellular.* No significant differences were noted.

b. 60 seconds

(1) *Color.*

(1) Type. No evidence of chunking.

(2) Threat. No evidence of chunking.

(3) Type and Threat. No evidence of chunking.

(4) Quadrants. In the unsaturated display, there was complete selection for Quadrant 4 and against Quadrants 1 and 2.

In the saturated display, there was partial selection for Quadrants 2 and 4.

(2) *Monochrome.*

(1) Type. No evidence of chunking.

(2) Threat. No evidence of chunking.

(3) Type and Threat. No evidence of chunking.

(4) Quadrants. In the unsaturated display, complete selection occurred for Quadrant 3.

In the saturated display, there was complete selection for Quadrant 2 and against Quadrant 3. There was also partial selection against Quadrant 1.

(3) *Intercellular.* No significant differences noted.

3. **SubBatch 2**

a. 10 seconds

(1) *Color.*

(1) Type. No evidence of chunking.

(2) Threat. No evidence of chunking.

(3) Type and Threat. No evidence of chunking.

(4) Quadrants. In the unsaturated display, there was complete selection for Quadrant 4. There was also partial selection against Quadrants 2 and 3.

In the saturated displays, there was partial selection for Quadrants 2 and 3.

(2) *Monochrome.*

(1) Type. No evidence of chunking.

(2) Threat. No evidence of chunking.

(3) Type and Threat. No evidence of chunking.

(4) Quadrants. In the unsaturated display, there was complete selection for Quadrant 2. There was partial selection against Quadrant 1.

In the saturated display, there was complete selection for Quadrant 2.

(3) *Intercellular.* No significant differences were noted.

b. 60 seconds

(1) *Color.*

(1) Type. No evidence of chunking.

(2) Threat. No evidence of chunking.

(3) Type and Threat. No evidence of chunking.

(4) Quadrants. In the unsaturated display, there was complete selection for Quadrant 1 and against Quadrant 4. There was also partial selection against Quadrant 2.

In the saturated display, there was complete selection for Quadrant 2 and against Quadrant 1. There was partial selection against Quadrant 3.

(2) *Monochrome.*

(1) Type. No evidence of chunking.

(2) Threat. In the unsaturated display, there was complete selection against the friendly element.

(3) Type and Threat. No evidence of chunking.

(4) Quadrants. In the unsaturated display, there was complete selection for Quadrant 3 and against Quadrant 1. There was partial selection against Quadrant 2.

In the saturated display, there was complete selection against Quadrant 1.

(3) *Intercellular.* The only difference was the occurrence of threat chunking in the unsaturated monochrome cell.

Given the multiple occurrence of quadrant chunking, an attempt was made to see if any type of pattern could be determined, relative to color/monochrome. All the results were pooled and then compared. The only significant difference occurred in the 60 second, unsaturated pooling. The color cell had 50% more significant complete quadrant selections than did the monochrome cell. By specific quadrants, the color cell had more complete selections in Quadrants 1 and 4 than did the monochrome cell.

4. Initial Chunking Conclusions

1) The basic null hypothesis that chunking would not occur is not valid. Quadrant chunking was dominant with some threat chunking. The majority of subjects felt they were using quadrants (either alone or in conjunction with Type/Threat) to recall information.

2) Overall, the extended null hypothesis that color would not affect chunking is valid. There was only one case where color appeared to assist in quadrant chunking. Also, in the ten second saturated display better threat chunking occurred in the color display.

3) Despite questionnaire data to show that Type/Threat chunking was being used, very little evidence is shown for its effectiveness. There is no evidence that Type and Threat Chunking (i.e., all hostile submarines) was effective.

4) Chunking seemed to occur more often and within more groups when the display was saturated.

5) Chunking was no more prevelant in the subjects who were familiar with NTDS than it was amongst those subjects who were unfamiliar with NTDS.

6) An attempt was made to see whether the amount of time used to chunk (Badre, 1982, p. 501) or the total time needed to accomplish a task (reconstruction) varied with display type (color or monochrome). No significant differences were noted.

IV. CONCLUSIONS

A. OVERVIEW

Chapter III presented the basic analysis of this experiment and the initial conclusions reached as a result of that analysis. The primary purpose of the present chapter is to look at those conclusions and determine if the hypotheses presented in Chapter Two were indeed valid.

Finally, some thought will be given to the practical implications of this experiment. Specifically, the key question in this area is; would the implementation of a system of partially redundant color coded displays be worth the time, effort, and most significantly, expense.

To summarize, the following null hypotheses were proposed at the beginning of the experiment for testing.

1) HYPOTHESIS 1.

Color would have no effect on a subjects ability to perform a Search and Detection (S & D) Task.

2) HYPOTHESIS 2.

Color would have no effect on an S & D task in a high target versus low target (saturated vs unsaturated) environment.

3) HYPOTHESIS 3.

Color would have no effect on a S & D task when the subjects exposure time to the display was varied from short (10 seconds) to long (60 seconds).

4) HYPOTHESIS 4.

The effect of color, if any, would not be influenced by the subject's previous experience with the code.

5) HYPOTHESIS 5.

Subjects would utilize some form of chunking to recall target information, but it would not be effected by the addition of color to the displays.

In addition to the above hypothesis, another null hypothesis was suggested during the basic analysis of the data.

6) HYPOTHESIS 6.

There would be no synergistic effects between the basic factors of time, density, and color.

There were also three underlying null hypotheses tested in this experiment, which interrelate to the first five hypotheses.

7) HYPOTHESIS 7.

An increase in exposure time would not effect performance regardless of display density or color.

8) HYPOTHESIS 8.

An increase in target saturation would not effect performance regardless of exposure time or color.

9) HYPOTHESIS 9.

Chunking would occur regardless of display density, exposure time, or the color coding in effect.

B. EFFECT OF COLOR

The analysis results would seem to disprove hypotheses one and six. Whether acting alone, or in some form of synergism with the other basic factors, the addition of color resulted in an overall improvement in performance of 14.1%. This effect was strongest in SubBatch 2 (those subjects Unfamiliar with NTDS symbology). SubBatch 2 showed an overall performance improvement of 17.2%. As mentioned in Chapter III, research has shown that the more unfamiliar a code, the more color would be of benefit in the task. (Teichner, 1977, p. 17) However, SubBatch 1 also showed a strong overall improvement of 14.1%. This improvement could be attributable to better chunking - despite the fact that the chunking analysis did not indicate any effect due to color. An additional possibility is that the artificiality of the experiment (classroom environment with slide projected displays) may have nullified any experience factor, hence making both subbatches, in effect, 'unfamiliar' with the code. According to Frey (1976), color should cease to be an improvement factor as the subjects familiarity with the code increases. Since SubBatch 1 did show definite improvement, there would seem

to be 2 possible explanations.The first is that the subjects were not as experienced as defined by Frey (the above artificiality explanation might also account for this). The second possibility is that chunking was in fact improved by the addition of color, but the analytical proof was masked by unaccounted for variables in the experiment.

Color seems to have had a greater positive effect when coupled with changing exposure times. As exposure time increased, more improvements in the subjects performance were noted for the color cell than for the monochrome cell. This was especially apparent in SubBatch 1 (this seems to support the idea of more effective chunking by SubBatch 1). This analysis would seem to disprove hypothesis number three.

Color seems to have very little or no effect when viewed in conjunction with display density. Relative to the monochrome display, color is neither any better or any worse. This section of the analysis tends to support hypothesis two.

As discussed previously, color seems to have had no apparent effect on the subjects mechanisms for chunking data. However, inferences from other areas of experimental analysis appear to indicate that chunking could be enhanced by the addition of color. The analysis also seems to indicate that this enhancement would be marginal and not of any overwhelming consequence. A possible explanation for this fact could be that while color provides the subject with an additional strategy path, especially for those familiar with the symbology, this strategy has a much lower priority in the chunk than the more prevalent quadrant chunking.

Finally, the analysis seems to support hypothesis number four. Regardless of the subjects knowledge level, the two SubBatches indicated relatively small differences in improvement with skill level (i.e., 14.1% versus 17.2%).

C. UNDERLYING CONCLUSIONS

This analysis did not support hypothesis number eight. With longer exposure times, significant improvements were noted, regardless of the type of display being viewed. This result was expected as it was assumed an increase in available viewing time would allow more time for the development and employment of an effective chunking strategy, or simply to conduct more chunking, regardless of effectiveness.

The analysis did not support hypothesis number nine. For the most part, the more saturated a given display, the more improvement was noted. This result could be due to the increased number of items available in the field. In other words, the

subjects had more paths to use in chunking (shape, location, number, color, patterns). This may have reduced the number of chunks, but also increased the number of elements in each chunk, thus increasing overall the number of correct responses. This would support more effective chunking when the intricacy of the display increases.

As shown throughout the previous paragraphs, hypothesis nine, chunking, is a valid idea. In setting up the experiment, it was expected that tactical relationships would be used to form the chunks, in fact the displays were created utilizing tactical relationships between the symbols used. This method was mentioned by the subjects in the questionnaire responses, but a quadrant strategy (geometric relationship) seems to have been the dominant method employed. Given the perceptions of the test subjects, it could be that quadrant chunking was the overall method used, but selection of initial quadrant, and recall of the symbols within it may have been based on tactical relationships. Insufficient information is available to determine if this was indeed the case.

D. DISCUSSION

One more question remains- specifically, does the improvement factor indicated by a partially redundant color code justify modifying current systems to implement it. The most pressing factor relating to this question revolves around the cost of such upgrading. This cost would be spread throughout a system, software modifications, personnel training, and most importantly, hardware. In one ASWPRO study (Campbell, 1980, pp. 42-43), it was stated that the cost difference between comparable color over monochrome systems was a two fold increase. Comparable being defined as identical memory available for data processing, same raster scan rates, and at same comparative level of technology. Given current 1986 technology, the cost of color upgrade would still be significant (the cost of color components over monochrome is still roughly 2:1).

The results of this experiment seem to indicate approximately a 14% increase in performance with color displays. This level of increase would appear at first to be significant in the data overload world of a Combat Information Center. The key factor that must be considered is that these results occured in a very controlled environment were the only concerns were plotting the data points correctly. A CIC under Combat conditions is a very noisy and distracting place, the effect of color coding may be better or worse under actual conditions. A review of the available Literature indicates that,

to date, no studies utilizing color codes codes in realistic military environments have been completed. Therefore, no firm commitment for or against employment of a color code can be made.

Another way of looking at the results would be to see which display type resulted in more robust performance under stress. Neither display seemed to aid performance when time was the constraining factor (i.e., at 10 seconds). When density was also included, both color and monochrome displays reflected the same degree of improvement as density increased and viewing time remained short. As viewing time increased to 60 seconds, the color displays showed improvement over the monochrome ones. These results would seem to indicate that under some types of stress (short viewing time with lots of targets), it does not matter what type of display you have (color or monochrome), in other situations (long viewing time and lots of targets) color appears to help. Given the need for quick responses to what essentially would be short viewing time data, color may not be of any real benefit in a tactical plot.

The impact of the discussion is to bring out the requirement for defining exactly what a partially redundant color code is expected to do for the operator. It appears it will not improve performance under all conditions. It can be of benefit in certain aspects of employment such as new users, or long decision making times. The results of this experiment seem to indicate it may not be of any tangible benefit under very rapid response conditions. Therefore, given the limited nature of this analysis-- limited subjects, artificial environment, only 1 type of tactical display employed-- it would seem that the addition of partially redundant color coding should not be considered an overriding priority in attempts to improve tactical data assimilation.

APPENDIX A
EXPERIMENTAL MATERIALS

This appendix shows the experimental materials, the pixel mapping and the subject descriptions.

SCENARIO

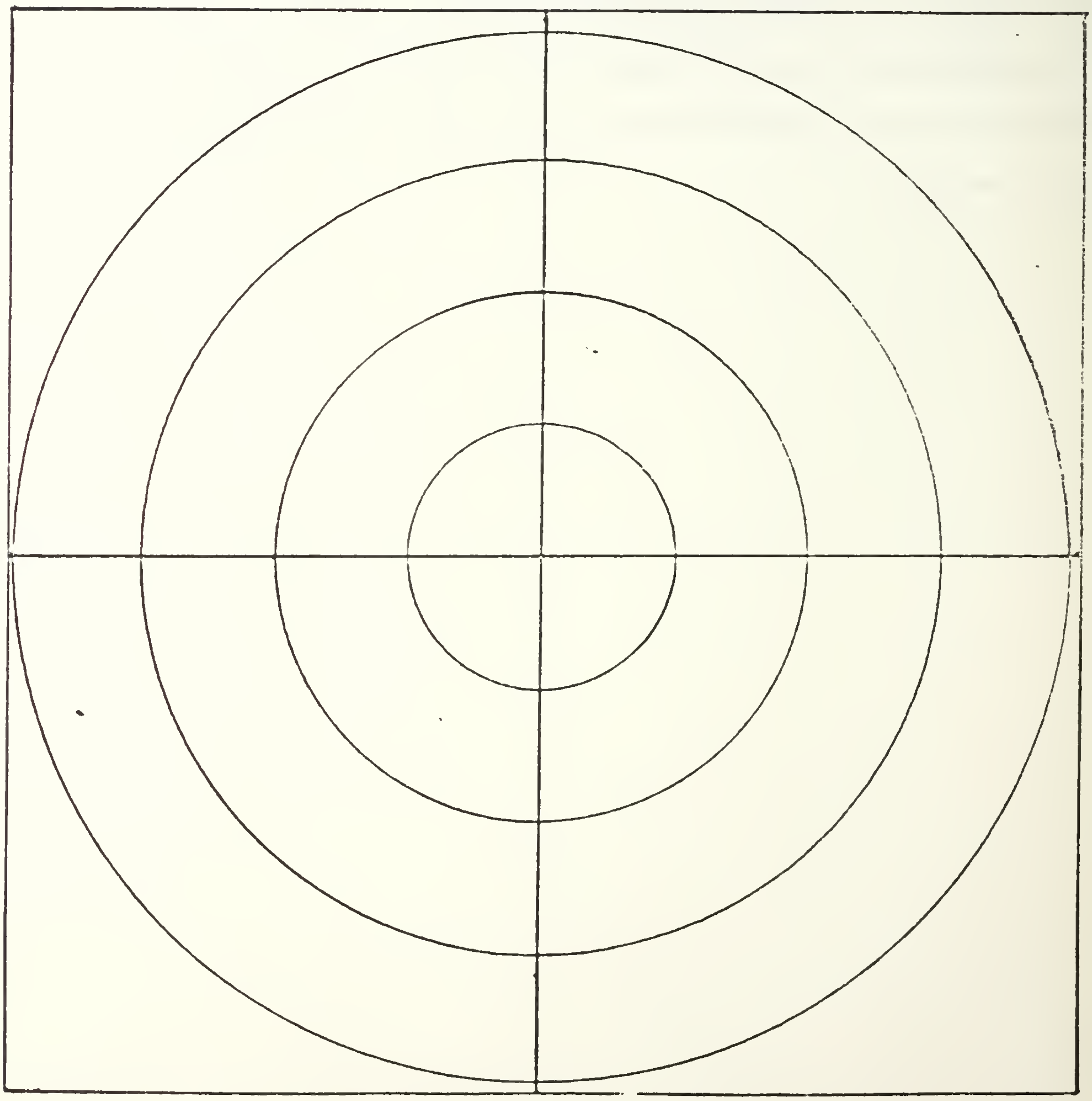
You are the AntiSubmarine Warfare Commander (ASWC) aboard the USS Coral Sea. Your Battlegroup is in an increased readiness status due to recent political problems in Libya.

You have just entered the ASW CIC and are preparing the ASW Situation Brief for the BG Commander. Unfortunately, shortly after you begin, the NTDS screen goes blank. Luckily, there are some blank NTDS forms lying around CIC so you can reconstruct the current display. The Admiral will expect a thorough tactical briefing from you.

RECONSTRUCTION SHEET

NTDS SYMBOLOGY

SYMBOL	COLOR	DESCRIPTION
	BLUE	FRIENDLY SURFACE
	BLUE	FRIENDLY AIR
	BLUE	FRIENDLY SUB
	RED	HOSTILE SURFACE
	RED	HOSTILE AIR
	RED	HOSTILE SUB
	GREEN	NEUTRAL SURFACE
	GREEN	NEUTRAL AIR
	GREEN	NEUTRAL SUB



Questionaire

[1] Describe your "tactic" for reconstructing the display [ie by quadrant, subgroupings, threat].

Did your tactic change as the exposure time changed?

Did your tactic change as the density changed?

Did your tactic change as the experiment progressed?

IF YOUR DISPLAYS ONLY HAD ONE COLOR GO TO QUESTION 3.

[2] Did color aid or distract you in the: 10 sec viewing?

60 sec viewing?

[3] Was the 10 second viewing time:

a] sufficient
b] too long
c] too short

when the display was saturated?

when the display was unsaturated?

[4] Was the 60 second Viewing time:

a] sufficient
b] too long
c] too short

when the display was saturated?

when the display was unsaturated?

[5] We would appreciate any comments you have about the experiment. Thank you.

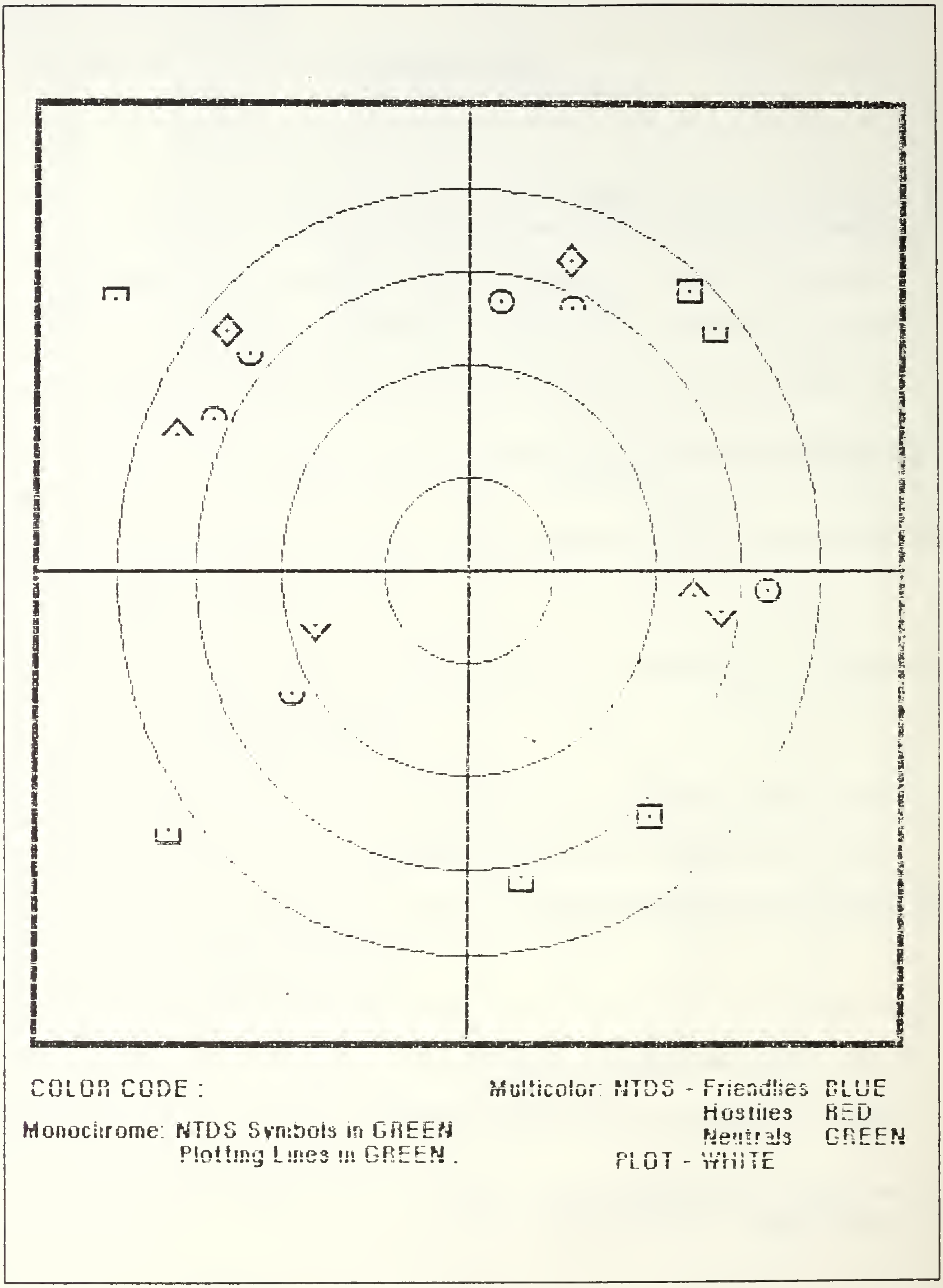


Figure A.1 Unsaturated Display.

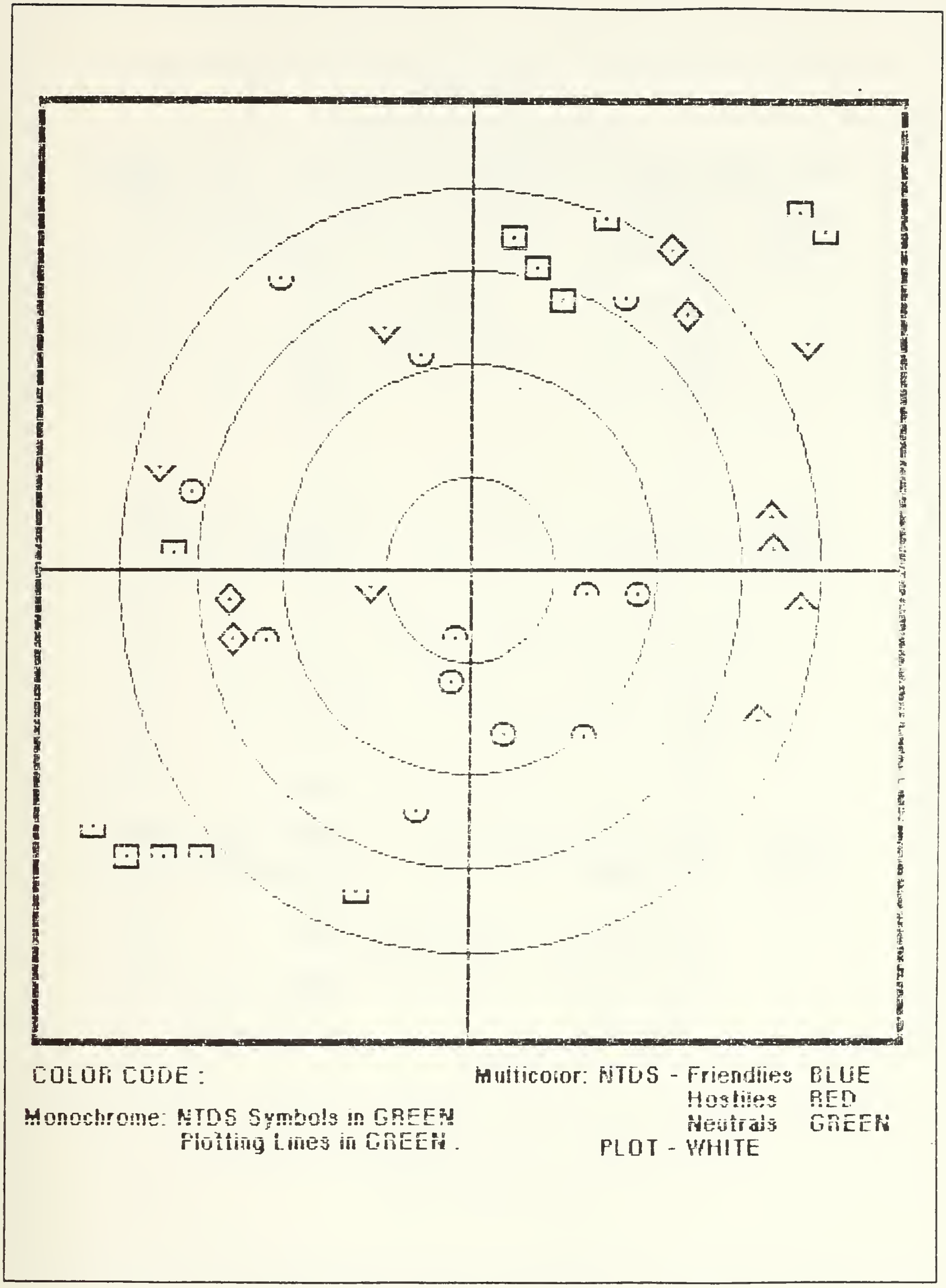


Figure A.2 Saturated Display.

```
Navy Tactical Data System Symbology PIXEL Maps

GROUP:  Friendly Contacts    Color Coded: BLUE
TYPES:   Surface       Air        Submarine

           xxx          xxxx
          x   x        x    x
         x     x      xx    xx
         x  x  x      x  xx  x     x  xx  x
         x     x                   xx    xx
          x   x                     x    x
           xxx                       xxxx


GROUP:  Hostile  Contacts    Color Coded: RED
TYPES:   Surface         Air        Submarine

            x            x
           x x          x x
          x   x        x   x
         x  x  x      x  x  x      x  x  x
          x   x                     x   x
           x x                       x x
            x                         x


GROUP:  Neutral  Contacts    Color Coded: GREEN
TYPES:   Surface         Air        Submarine

         xxxxxxx      xxxxxxx
         x     x      x     x
         x     x      x     x
         x  x  x      x  x  x      x  x  x
         x     x                   x     x
         x     x                   x     x
         xxxxxxx                   xxxxxxx
```

Figure A.3 Pixel Mapping.

TABLE 25

SUBJECT BACKGROUND

Subject	Desig	SubBatch	Display Type
1	1110	1	M
2	1110	1	M
3	1110	1	M
4	1110	1	M
5	1110	1	M
6	1100	1	M
7	1110	1	C
8	1110	1	C
9	1110	1	C
10	1110	1	C
11	1320	2	M
12	CAND	2	M
13	1120	2	M
14	1320	2	M
15	1100	2	M
16	1110	2	M
17	1310	2	C
18	1105	2	C
19	1100	2	C
20	1100	2	C

APPENDIX B
SELECTED MINITAB RESULTS

The first 3 figures of this appendix show raw Batch data, displayed graphically to show the effect of color on the subjects.

The next 9 figures, shows an illustrative set of AOV results, as prepared by MINITAB. This example set is from the Chunking Analysis.

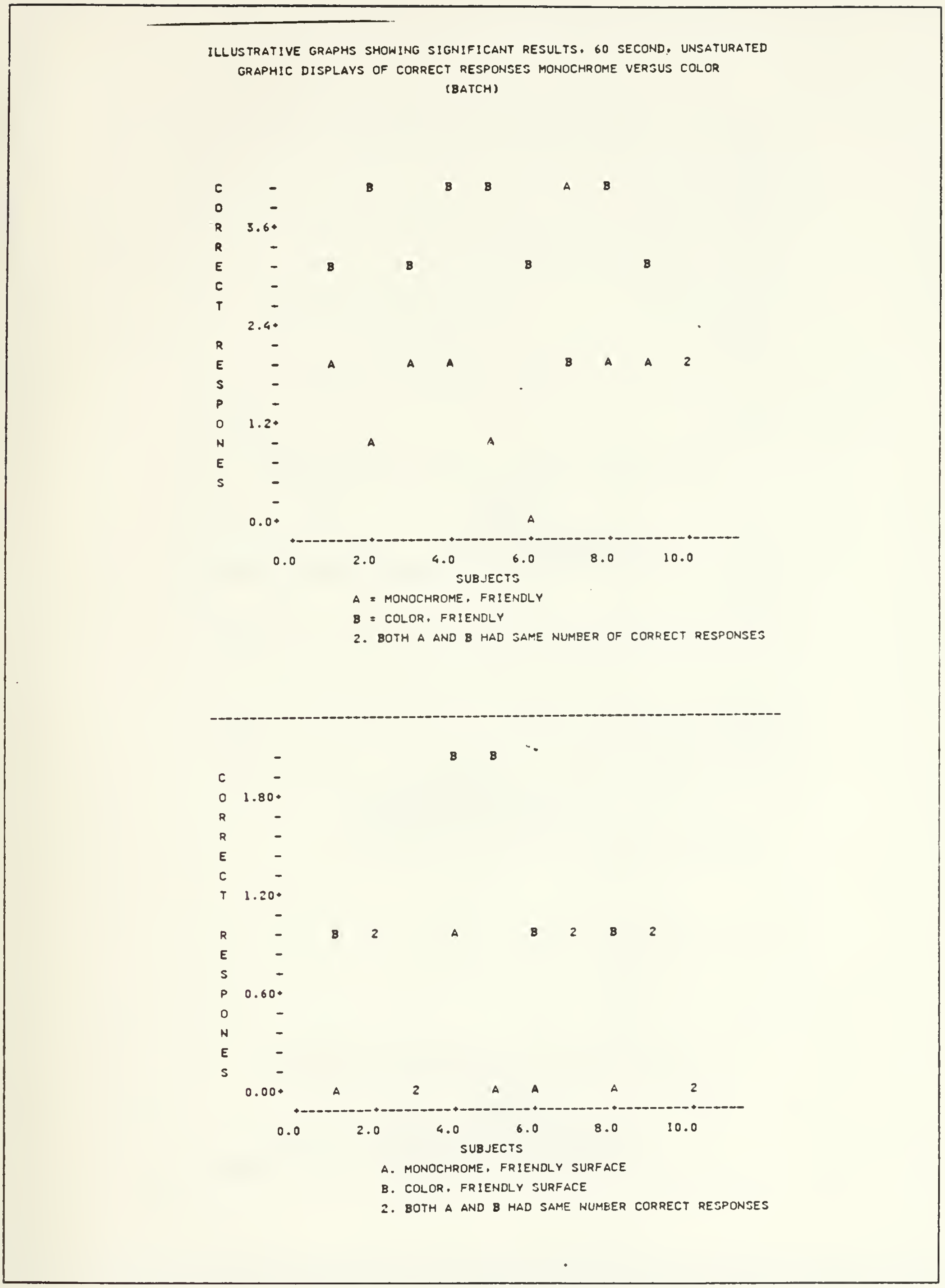
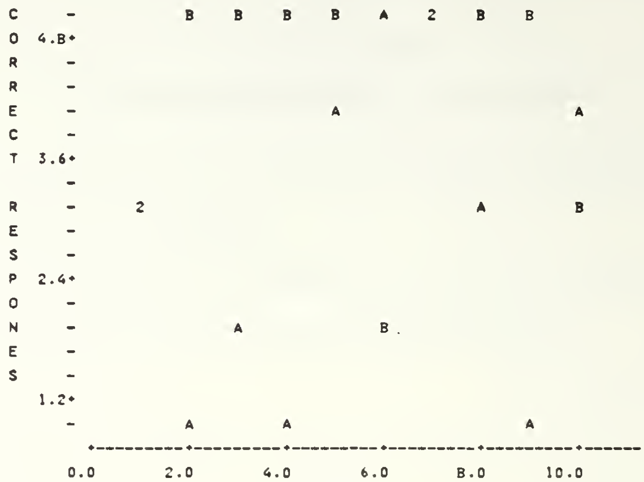
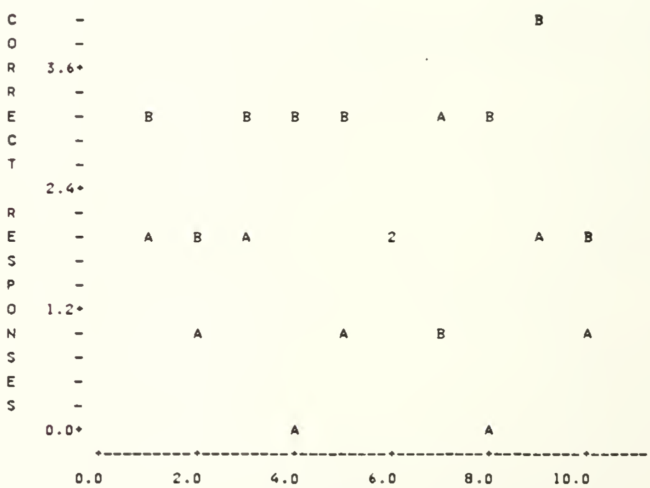


Figure B.1 Raw Data Graphs I.



A. MONOCHROME, CIRCLE 4
B. COLOR, CIRCLE 4
2. BOTH A AND B HAD SAME NUMBER OF CORRECT RESPONSES



A. MONOCHROME, QUADRANT 1, CIRCLE 4
B. COLOR, QUADRANT 1, CIRCLE 4
2. BOTH A AND B HAD SAME NUMBER OF CORRECT RESPONSES

Figure B.2 Raw Data Graphs II.

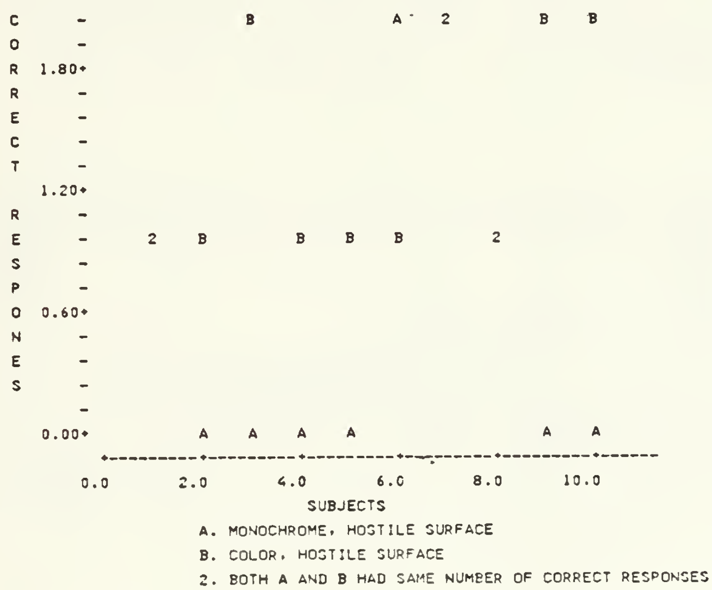


Figure B.3 Raw Data Graph III.

```
ILLUSTRATIVE EXAMPLES OF AOV SIGNIFICANT DIFFERENCES
 SIGNIFICANT DIFFERENCES: CHUNKING ANALYSIS  BATCH
             (F-RATIO > 4.41)

FRIENDLY (E 5) VERSUS HOSTILE (E 6) COLOR 10SEC UNSATURATED
ANALYSIS OF VARIANCE
SOURCE     DF        SS        MS        F
FACTOR      1      9.80      9.80     7.88
ERROR      18     22.40      1.24
TOTAL      19     32.20
                                   INDIVIDUAL 95 PCT CI'S FOR MEAN
                                   BASED ON POOLED STDEV
LEVEL       N      MEAN     STDEV  --+---------+---------+---------+----
E 5        10     0.600     0.843  (---------*---------)
E 6        10     2.000     1.333                 (---------*---------)
                                   --+---------+---------+---------+----
POOLED STDEV =    1.116            0.00      0.80      1.60      2.40



FRIENDLY (E 5) VERSUS HOSTILE (E 6) COLOR 10SEC SATURATED
ANALYSIS OF VARIANCE
SOURCE     DF        SS        MS        F
FACTOR      1     26.45     26.45     7.52
ERROR      18     63.30      3.52
TOTAL      19     89.75
                                   INDIVIDUAL 95 PCT CI'S FOR MEAN
                                   BASED ON POOLED STDEV
LEVEL       N      MEAN     STDEV  -----+---------+---------+---------+-
E 5        10     0.600     0.966  (---------*---------)
E 6        10     2.900     2.470                 (---------*---------)
                                   -----+---------+---------+---------+-
POOLED STDEV =    1.875                0.0       1.4       2.8       4.2



FRIENDLY (E 5) VERSUS NEUTRAL (E 7) COLOR 10SEC SATURATED
ANALYSIS OF VARIANCE
SOURCE     DF        SS        MS        F
FACTOR      1     18.05     18.05     7.57
ERROR      18     42.90      2.38
TOTAL      19     60.95
                                   INDIVIDUAL 95 PCT CI'S FOR MEAN
                                   BASED ON POOLED STDEV
LEVEL       N      MEAN     STDEV  ----+---------+---------+---------+--
E 5        10     0.600     0.966  (---------*---------)
E 7        10     2.500     1.958                 (---------*--------)
                                   ----+---------+---------+---------+--
POOLED STDEV =    1.544               0.0       1.2       2.4       3.6
```

Figure B.4   AOV Results: Chunking Analysis I.

```
SURFACE (E 3) VERSUS SUBMARINE (E 4) COLOR 60SEC SATURATED
ANALYSIS OF VARIANCE
SOURCE     DF        SS        MS        F
FACTOR      1     92.45     92.45    17.32
ERROR      18     96.10      5.34
TOTAL      19    188.55
                                 INDIVIDUAL 95 PCT CI'S FOR MEAN
                                 BASED ON POOLED STDEV
LEVEL       N      MEAN     STDEV  ---+---------+---------+---------+---
E 3        10     7.300     2.003                       (-------*------)
E 4        10     3.000     2.582  (-------*-------)
                                   ---+---------+---------+---------+---
POOLED STDEV =    2.311               2.0       4.0       6.0       8.0
```

```
SURFACE (E 3) VERSUS  SUBMARINE (E 4) MONOCHROME 10SEC SATURATED
ANALYSIS OF VARIANCE
SOURCE     DF        SS        MS        F
FACTOR      1     24.20     24.20    12.81
ERROR      18     34.00      1.89
TOTAL      19     58.20
                                 INDIVIDUAL 95 PCT CI'S FOR MEAN
                                 BASED ON POOLED STDEV
LEVEL       N      MEAN     STDEV  ---+---------+---------+---------+---
E 3        10     2.800     1.687                    (------*-------)
E 4        10     0.600     0.966  (-------*-------)
                                   ---+---------+---------+---------+---
POOLED STDEV =    1.374               0.0       1.2       2.4       3.6
```

```
FRIENDLY (E 5) VERSUS HOSTILE (E 6) MONOCHROME 60SEC UNSATURATED
ANALYSIS OF VARIANCE
SOURCE     DF        SS        MS        F
FACTOR      1     11.25     11.25     7.31
ERROR      18     27.70      1.54
TOTAL      19     38.95
                                 INDIVIDUAL 95 PCT CI'S FOR MEAN
                                 BASED ON POOLED STDEV
LEVEL       N      MEAN     STDEV  -+---------+---------+---------+-----
E 5        10     1.800     1.033   (-------*-------)
E 6        10     3.300     1.418                (-------*-------)
                                   -+---------+---------+---------+-----
POOLED STDEV =    1.241            1.0       2.0       3.0       4.0
```

Figure B.5 AOV Results: Chunking Analysis II.

```
SURFACE (E 3) VERSUS SUBMARINE (E 4) MONOCHROME 60SEC SATURATED
ANALYSIS OF VARIANCE
SOURCE      DF         SS         MS         F
FACTOR       1      51.20      51.20     15.16
ERROR       18      60.80       3.38
TOTAL       19     112.00
                                   INDIVIDUAL 95 PCT CI'S FOR MEAN
                                   BASED ON POOLED STDEV
LEVEL        N      MEAN      STDEV  ---+---------+---------+---------+---
E 3         10     5.600      1.897                        (-------*-------)
E 4         10     2.400      1.776  (-------*-------)
                                     ---+---------+---------+---------+---
POOLED STDEV =     1.838                1.6       3.2       4.8       6.4
```

```
FRIENDLY (E 5) VERSUS NEUTRAL (E 7) MONOCHROME 60SEC SATURATED
ANALYSIS OF VARIANCE
SOURCE      DF         SS         MS         F
FACTOR       1      39.20      39.20      6.88
ERROR       18     102.60       5.70
TOTAL       19     141.80
                                   INDIVIDUAL 95 PCT CI'S FOR MEAN
                                   BASED ON POOLED STDEV
LEVEL        N      MEAN      STDEV  -----+---------+---------+---------+-
E 5         10     2.700      2.669   (-------*------)
E 7         10     5.500      2.068                (-------*------)
                                     -----+---------+---------+---------+-
POOLED STDEV =     2.387                  2.0       4.0       6.0       8.0
```

Figure B.6 AOV Results: Chunking Analysis III.

```
    SIGNIFICANT DIFFERENCES: CHUNKING ANALYSIS SUBBATCH I
        (F RATIO >5.99)

FRIENDLY (E 5) VERSUS HOSTILE (E 6) COLOR 10 SEC UNSATURATED

ANALYSIS OF VARIANCE
SOURCE      DF        SS        MS        F
FACTOR       1     45.12     45.12    34.94
ERROR        6      7.75      1.29
TOTAL        7     52.87
                                    INDIVIDUAL 95 PCT CI'S FOR MEAN
                                    BASED ON POOLED STDEV
LEVEL        N      MEAN     STDEV  ----+---------+---------+---------+--
E 5          4     0.500     1.000  (-----*-----)
E 6          4     5.250     1.258                    (-----*-----)
                                    ----+---------+---------+---------+--
POOLED STDEV =     1.137               0.0       2.4       4.8       7.2

HOSTILE (E 6) VERSUS NEUTRAL (E 7)COLOR 10 SEC SATURATED

ANALYSIS OF VARIANCE
SOURCE      DF        SS        MS        F
FACTOR       1     24.50     24.50     6.84
ERROR        6     21.50      3.58
TOTAL        7     46.00
                                    INDIVIDUAL 95 PCT CI'S FOR MEAN
                                    BASED ON POOLED STDEV
LEVEL        N      MEAN     STDEV  ---+---------+---------+---------+---
E 6          4     5.250     1.258               (---------*---------)
E 7          4     1.750     2.363   (--------*---------)
                                    ---+---------+---------+---------+---
POOLED STDEV =     1.893              0.0       2.4       4.8       7.2


FRIENDLY (E 5) VERSUS HOSTILE (E 6) COLOR 60 SEC UNSATURATED
ANALYSIS OF VARIANCE
SOURCE      DF        SS        MS        F
FACTOR       1     4.500     4.500     5.40
ERROR        6     5.000     0.833
TOTAL        7     9.500
                                    INDIVIDUAL 95 PCT CI'S FOR MEAN
                                    BASED ON POOLED STDEV
LEVEL        N      MEAN     STDEV  -----+---------+---------+---------+-
E 5          4    3.0000    0.8165   (--------*--------)
E 6          4    4.5000    1.0000             (---------*--------)
                                    -----+---------+---------+---------+-
POOLED STDEV =    0.9129                2.4       3.6       4.8       6.0
```

Figure B.7   AOV Results: Chunking Analysis IV.

```
AIR (E 2) VERSUS SURFACE (E 3) MONOCHROME 10SEC UNSATURATED

ANALYSIS OF VARIANCE
SOURCE      DF          SS          MS          F
FACTOR       1       15.12       15.12       8.44
ERROR        6       10.75        1.79
TOTAL        7       25.87
                                         INDIVIDUAL 95 PCT CI'S FOR MEAN
                                         BASED ON POOLED STDEV
LEVEL        N        MEAN       STDEV   --+---------+---------+---------+----
E 2          4       1.250       1.500   (-------*-------)
E 3          4       4.000       1.155                 (-------*-------)
                                         --+---------+---------+---------+----
POOLED STDEV =       1.339                 0.0       2.0       4.0       6.0


SURFACE (E 3) VERSUS SUBMARINE (E 4)  MONOCHROME 10SEC SATURATED
ANALYSIS OF VARIANCE
SOURCE      DF          SS          MS          F
FACTOR       1      24.500      24.500      29.40
ERROR        6       5.000       0.833
TOTAL        7      29.500
                                         INDIVIDUAL 95 PCT CI'S FOR MEAN
                                         BASED ON POOLED STDEV
LEVEL        N        MEAN       STDEV   ----+---------+---------+---------+--
E 3          4      4.0000      1.1547                         (------*------)
E 4          4      0.5000      0.5774   (------*------)
                                         ----+---------+---------+---------+--
POOLED STDEV =      0.9129                  0.0       1.6       3.2       4.8


FRIENDLY (E 5) VERSUS NEUTRAL (E 7) MONOCHROME 60SEC SATURATED
ANALYSIS OF VARIANCE
SOURCE      DF          SS          MS          F
FACTOR       1       32.00       32.00       8.00
ERROR        6       24.00        4.00
TOTAL        7       56.00
                                         INDIVIDUAL 95 PCT CI'S FOR MEAN
                                         BASED ON POOLED STDEV
LEVEL        N        MEAN       STDEV   ----------+---------+---------+------
E 5          4       2.500       2.517   (-------*-------)
E 7          4       6.500       1.291                 (-------*-------)
                                         ----------+---------+---------+------
POOLED STDEV =       2.000                         3.0       6.0       9.0
```

Figure B.8 AOV Results: Chunking Analysis V.

```
FRIENDLY (E 5) VERSUS NEUTRAL (E 7) MONOCHROME 60SEC UNSATURATED
ANALYSIS OF VARIANCE
SOURCE      DF        SS         MS         F
FACTOR       1      8.33       8.33      5.43
ERROR       10     15.33       1.53
TOTAL       11     23.67
                                     INDIVIDUAL 95 PCT CI'S FOR MEAN
                                     BASED ON POOLED STDEV
LEVEL        N      MEAN      STDEV  ---------+---------+---------+-------
E 5          6     1.333      0.816   (--------*---------)
E 7          6     3.000      1.549                (--------*--------)
                                     ---------+---------+---------+-------
POOLED STDEV =     1.238                       1.2       2.4       3.6
```

```
SURFACE (E 3) VERSUS SUBMARINE (E 4) MONOCHROME 60SEC SATURATED
ANALYSIS OF VARIANCE
SOURCE      DF        SS         MS         F
FACTOR       1     36.75      36.75     10.16
ERROR       10     36.17       3.62
TOTAL       11     72.92
                                     INDIVIDUAL 95 PCT CI'S FOR MEAN
                                     BASED ON POOLED STDEV
LEVEL        N      MEAN      STDEV  ----------+---------+---------+------
E 3          6     5.333      2.066                  (--------*-------)
E 4          6     1.833      1.722   (-------*--------)
                                     ----------+---------+---------+------
POOLED STDEV =     1.902                       2.0       4.0       6.0
```

Figure B.9 AOV Results: Chunking Analysis VI.

```
FRIENDLY (E 5) VERSUS NEUTRAL (E 7) COLOR 60SEC SATURATED
ANALYSIS OF VARIANCE
SOURCE      DF        SS        MS        F
FACTOR       1     36.75     36.75     8.32
ERROR       10     44.17      4.42
TOTAL       11     80.92
                                    INDIVIDUAL 95 PCT CI'S FOR MEAN
                                    BASED ON POOLED STDEV
LEVEL        N      MEAN     STDEV  ------+---------+---------+---------+
E 5          6     2.833     2.137   (--------*---------)
E 7          6     6.333     2.066                 (---------*--------)
                                    ------+---------+---------+---------+
POOLED STDEV =     2.102                 2.0       4.0       6.0       8.0
```

```
FRIENDLY (E 5) VERSUS HOSTILE (E 6) MONOCHROME 60SEC UNSATURATED
ANALYSIS OF VARIANCE
SOURCE      DF        SS        MS        F
FACTOR       1     12.00     12.00     9.47
ERROR       10     12.67      1.27
TOTAL       11     24.67
                                    INDIVIDUAL 95 PCT CI'S FOR MEAN
                                    BASED ON POOLED STDEV
LEVEL        N      MEAN     STDEV  --------+---------+---------+--------
E 5          6     1.333     0.816   (-------*--------)
E 6          6     3.333     1.366                (--------*-------)
                                    --------+---------+---------+--------
POOLED STDEV =     1.125                   1.2       2.4       3.6
```

Figure B.10 AOV Results: Chunking Analysis VII.

```
    SIGNIFICANT DIFFERENCES: CHUNKING ANALYSIS SUBBATCH 2
      (F RATIO > 4.96)

SURFACE (E 3) VERSUS SUBMARINE (E 4) COLOR 10SEC SATURATED
ANALYSIS OF VARIANCE
SOURCE     DF        SS         MS         F
FACTOR      1     14.08      14.08      6.35
ERROR      10     22.17       2.22
TOTAL      11     36.25
                                    INDIVIDUAL 95 PCT CI'S FOR MEAN
                                    BASED ON POOLED STDEV
LEVEL       N      MEAN      STDEV  -----+---------+---------+---------+-
E 3         6     2.833      1.941                (--------*---------)
E 4         6     0.667      0.816  (---------*--------)
                                    -----+---------+---------+---------+-
POOLED STDEV =    1.489               0.0       1.4       2.8       4.2



FRIENDLY (E 5) VERSUS NEUTRAL (E 7) COLOR 10SEC SATURATED
ANALYSIS OF VARIANCE
SOURCE     DF        SS         MS         F
FACTOR      1     16.33      16.33      8.45
ERROR      10     19.33       1.93
TOTAL      11     35.67
                                    INDIVIDUAL 95 PCT CI'S FOR MEAN
                                    BASED ON POOLED STDEV
LEVEL       N      MEAN      STDEV  -----+---------+---------+---------+-
E 5         6     0.667      1.033   (--------*--------)
E 7         6     3.000      1.673                  (--------*--------)
                                    -----+---------+---------+---------+-
POOLED STDEV =    1.390               0.0       1.4       2.8       4.2



SURFACE (E 3) VERSUS SUBMARINE (E 4) COLOR 60SEC SATURATED
ANALYSIS OF VARIANCE
SOURCE     DF        SS         MS         F
FACTOR      1     65.33      65.33     13.71
ERROR      10     47.67       4.77
TOTAL      11    113.00
                                    INDIVIDUAL 95 PCT CI'S FOR MEAN
                                    BASED ON POOLED STDEV
LEVEL       N      MEAN      STDEV  ----------+---------+---------+------
E 3         6     6.833      1.941                     (-------*--------)
E 4         6     2.167      2.401   (-------*-------)
                                    ----------+---------+---------+------
POOLED STDEV =    2.183                        2.4       4.8       7.2
```

Figure B.11 AOV Results: Chunking Analysis VIII.

APPENDIX C
INTERCELLULAR ANALYSIS

The following tables show the elements which were significantly different for a given analytical test. The tables also show in which display the element was improved. If no differences occurred, there is no table for that analysis.

Tables 26-36 show the intercellular results for time, density, and color analysis. Tables 37-42 show the results of the qualitative comparisons discussed on pp. 50-51:

TABLE 26

TIME ANALYSIS I

Color 60 Seconds Unsaturated vs Monochrome 10 Seconds Unsaturated

Indicates COLOR Better Indicates MONOCHROME Better

SIGNIFICANT DIFFERENCES NOTED

Element	BATCH	SUB BATCH 1	SUB BATCH 2
Total			
Air			
Surface			
Submarine			
Friendly			
Hostile			
Neutral			
Fr Air			
Fr Surface			
Fr Submarine			
Hos Air			
Hos Surface			
Hos Submarine			
Neu Air			
Neu Surface			
Neu Submarine			
Quadrant 1			
Quadrant 2			
Quadrant 3			
Quadrant 4			
Circle 1			
Circle 2			
Circle 3			
Circle 4			
Circle 5			
Quad 1 Cr 1			
Quad 1 Cr 2			
Quad 1 Cr 3			
Quad 1 Cr 4			
Quad 1 Cr 5			
Quad 2 Cr 1			
Quad 2 Cr 2			
Quad 2 Cr 3			
Quad 2 Cr 4			
Quad 2 Cr 5			
Quad 3 Cr 1			
Quad 3 Cr 2			
Quad 3 Cr 3			
Quad 3 Cr 4			
Quad 3 Cr 5			
Quad 4 Cr 1			
Quad 4 Cr 2			
Quad 4 Cr 3			
Quad 4 Cr 4			
Quad 4 Cr 5			

TABLE 27

TIME ANALYSIS II

Monochrome 60 Seconds Unsaturated vs Color 10 Seconds Unsaturated

▓▓▓▓ Indicates COLOR Better ░░░░ Indicates MONOCHROME Better

SIGNIFICANT DIFFERENCES NOTED

Element	BATCH	SUB BATCH 1	SUB BATCH 2
Total			
Air	░░░░		
Surface	░░░░		
Submarine			
Friendly	░░░░	░░░░	
Hostile			
Neutral			░░░░
Fr Air			
Fr Surface	░░░░	░░░░	
Fr Submarine			
Hos Air			
Hos Surface			
Hos Submarine			
Neu Air			
Neu Surface			
Neu Submarine	░░░░		░░░░
Quadrant 1			
Quadrant 2	░░░░		
Quadrant 3			░░░░
Quadrant 4			
Circle 1			
Circle 2	░░░░	░░░░	
Circle 3			
Circle 4			
Circle 5			
Quad 1 Cr 1			
Quad 1 Cr 2			
Quad 1 Cr 3			
Quad 1 Cr 4			
Quad 1 Cr 5			
Quad 2 Cr 1			
Quad 2 Cr 2			
Quad 2 Cr 3			
Quad 2 Cr 4			
Quad 2 Cr 5			
Quad 3 Cr 1			
Quad 3 Cr 2	░░░░		
Quad 3 Cr 3	░░░░	░░░░	
Quad 3 Cr 4			░░░░
Quad 3 Cr 5	░░░░		
Quad 4 Cr 1			
Quad 4 Cr 2			
Quad 4 Cr 3			
Quad 4 Cr 4			
Quad 4 Cr 5			

TABLE 28

TIME ANALYSIS III

Color 60 Seconds Saturated vs Monochrome 10 Seconds Saturated

■ Indicates COLOR Better   ■ Indicates MONOCHROME Better

SIGNIFICANT DIFFERENCES NOTED

Element	BATCH	SUB BATCH 1	SUB BATCH 2
Total			
Air			
Surface			
Submarine	■	■	
Friendly			
Hostile	■	■	
Neutral			
Fr Air			■
Fr Surface			
Fr Submarine	■		
Hos Air			
Hos Surface	■		
Hos Submarine		■	
Neu Air			■
Neu Surface			
Neu Submarine	■		
Quadrant 1			
Quadrant 2		■	
Quadrant 3			■
Quadrant 4		■	
Circle 1		■	
Circle 2			■
Circle 3	■	■	■
Circle 4			■
Circle 5			
Quad 1 Cr 1			
Quad 1 Cr 2			
Quad 1 Cr 3			
Quad 1 Cr 4			
Quad 1 Cr 5			
Quad 2 Cr 1			
Quad 2 Cr 2			
Quad 2 Cr 3	■	■	
Quad 2 Cr 4			■
Quad 2 Cr 5			
Quad 3 Cr 1			■
Quad 3 Cr 2			
Quad 3 Cr 3	■		■
Quad 3 Cr 4		■	
Quad 3 Cr 5	■	■	
Quad 4 Cr 1			
Quad 4 Cr 2		■	
Quad 4 Cr 3			
Quad 4 Cr 4			■
Quad 4 Cr 5			

TABLE 29

TIME ANALYSIS IV

Monochrome 60 Seconds Saturated vs Color 10 Seconds Saturated

Indicates COLOR Better Indicates MONOCHROME Better

SIGNIFICANT DIFFERENCES NOTED

Element	BATCH	SUB BATCH 1	SUB BATCH 2
Total			
Air			
Surface			
Submarine			
Friendly			
Hostile			
Neutral			
Fr Air			
Fr Surface			
Fr Submarine			
Hos Air			
Hos Surface			
Hos Submarine			
Neu Air			
Neu Surface			
Neu Submarine			
Quadrant 1			
Quadrant 2			
Quadrant 3			
Quadrant 4			
Circle 1			
Circle 2			
Circle 3			
Circle 4			
Circle 5			
Quad 1 Cr 1			
Quad 1 Cr 2			
Quad 1 Cr 3			
Quad 1 Cr 4			
Quad 1 Cr 5			
Quad 2 Cr 1			
Quad 2 Cr 2			
Quad 2 Cr 3			
Quad 2 Cr 4			
Quad 2 Cr 5			
Quad 3 Cr 1			
Quad 3 Cr 2			
Quad 3 Cr 3			
Quad 3 Cr 4			
Quad 3 Cr 5			
Quad 4 Cr 1			
Quad 4 Cr 2			
Quad 4 Cr 3			
Quad 4 Cr 4			
Quad 4 Cr 5			

TABLE 30

DENSITY ANALYSIS I

Monochrome 10 Seconds Saturated vs Color 10 Seconds Unsaturated

Indicates COLOR Better Indicates MONOCHROME Better

SIGNIFICANT DIFFERENCES NOTED

Element	BATCH	SUB BATCH 1	SUB BATCH 2
Total			
Air			
Surface			
Submarine			
Friendly			
Hostile			
Neutral			
Fr Air			
Fr Surface			
Fr Submarine			
Hos Air			
Hos Surface			
Hos Submarine			
Neu Air			
Neu Surface			
Neu Submarine			
Quadrant 1			
Quadrant 2			
Quadrant 3			
Quadrant 4			
Circle 1			
Circle 2			
Circle 3			
Circle 4			
Circle 5			
Quad 1 Cr 1			
Quad 1 Cr 2			
Quad 1 Cr 3			
Quad 1 Cr 4			
Quad 1 Cr 5			
Quad 2 Cr 1			
Quad 2 Cr 2			
Quad 2 Cr 3			
Quad 2 Cr 4			
Quad 2 Cr 5			
Quad 3 Cr 1			
Quad 3 Cr 2			
Quad 3 Cr 3			
Quad 3 Cr 4			
Quad 3 Cr 5			
Quad 4 Cr 1			
Quad 4 Cr 2			
Quad 4 Cr 3			
Quad 4 Cr 4			
Quad 4 Cr 5			

TABLE 31

DENSITY ANALYSIS II

Color 60 Seconds Saturated vs Monochrome 60 Seconds Unsaturated

Indicates COLOR Better   Indicates MONOCHROME Better

SIGNIFICANT DIFFERENCES NOTED

Element	BATCH	SUB BATCH 1	SUB BATCH 2
Total			
Air			
Surface			
Submarine			
Friendly			
Hostile			
Neutral			
Fr Air			
Fr Surface			
Fr Submarine			
Hos Air			
Hos Surface			
Hos Submarine			
Neu Air			
Neu Surface			
Neu Submarine			
Quadrant 1			
Quadrant 2			
Quadrant 3			
Quadrant 4			
Circle 1			
Circle 2			
Circle 3			
Circle 4			
Circle 5			
Quad 1 Cr 1			
Quad 1 Cr 2			
Quad 1 Cr 3			
Quad 1 Cr 4			
Quad 1 Cr 5			
Quad 2 Cr 1			
Quad 2 Cr 2			
Quad 2 Cr 3			
Quad 2 Cr 4			
Quad 2 Cr 5			
Quad 3 Cr 1			
Quad 3 Cr 2			
Quad 3 Cr 3			
Quad 3 Cr 4			
Quad 3 Cr 5			
Quad 4 Cr 1			
Quad 4 Cr 2			
Quad 4 Cr 3			
Quad 4 Cr 4			
Quad 4 Cr 5			

TABLE 32
DENSITY ANALYSIS III

Monochrome 10 Seconds Unsaturated vs Color 10 Seconds Saturated

Indicates COLOR Better   Indicates MONOCHROME Better

SIGNIFICANT DIFFERENCES NOTED

Element	BATCH	SUB BATCH 1	SUB BATCH 2
Total			
Air			
Surface			
Submarine			
Friendly			
Hostile			
Neutral			
Fr Air			
Fr Surface			
Fr Submarine			
Hos Air			
Hos Surface			
Hos Submarine			
Neu Air			
Neu Surface			
Neu Submarine			
Quadrant 1			
Quadrant 2			
Quadrant 3			
Quadrant 4			
Circle 1			
Circle 2			
Circle 3			
Circle 4			
Circle 5			
Quad 1 Cr 1			
Quad 1 Cr 2			
Quad 1 Cr 3			
Quad 1 Cr 4			
Quad 1 Cr 5			
Quad 2 Cr 1			
Quad 2 Cr 2			
Quad 2 Cr 3			
Quad 2 Cr 4			
Quad 2 Cr 5			
Quad 3 Cr 1			
Quad 3 Cr 2			
Quad 3 Cr 3			
Quad 3 Cr 4			
Quad 3 Cr 5			
Quad 4 Cr 1			
Quad 4 Cr 2			
Quad 4 Cr 3			
Quad 4 Cr 4			
Quad 4 Cr 5			

TABLE 33

DENSITY ANALYSIS IV

Monochrome 10 Seconds Saturated vs Color 10 Seconds Unsaturated

Indicates COLOR Better Indicates MONOCHROME Better

	SIGNIFICANT	DIFFERENCES	NOTED
Element	BATCH	SUB BATCH 1	SUB BATCH 2
Total			
Air			
Surface			
Submarine			
Friendly			
Hostile			
Neutral			
Fr Air			
Fr Surface			
Fr Submarine			
Hos Air			
Hos Surface			
Hos Submarine			
Neu Air			
Neu Surface			
Neu Submarine			
Quadrant 1			
Quadrant 2			
Quadrant 3			
Quadrant 4			
Circle 1			
Circle 2			
Circle 3			
Circle 4			
Circle 5			
Quad 1 Cr 1			
Quad 1 Cr 2			
Quad 1 Cr 3			
Quad 1 Cr 4			
Quad 1 Cr 5			
Quad 2 Cr 1			
Quad 2 Cr 2			
Quad 2 Cr 3			
Quad 2 Cr 4			
Quad 2 Cr 5			
Quad 3 Cr 1			
Quad 3 Cr 2			
Quad 3 Cr 3			
Quad 3 Cr 4			
Quad 3 Cr 5			
Quad 4 Cr 1			
Quad 4 Cr 2			
Quad 4 Cr 3			
Quad 4 Cr 4			
Quad 4 Cr 5			

TABLE 34

COLOR ANALYSIS I

Color 60 Seconds Unsaturated vs Monochrome 60 Seconds Saturated

Indicates COLOR Better Indicates MONOCHROME Better

SIGNIFICANT DIFFERENCES NOTED

Element	BATCH	SUB BATCH 1	SUB BATCH 2
Total			
Air			
Surface			
Submarine			
Friendly			
Hostile			
Neutral			
Fr Air			
Fr Surface			
Fr Submarine			
Hos Air			
Hos Surface			
Hos Submarine			
Neu Air			
Neu Surface			
Neu Submarine			
Quadrant 1			
Quadrant 2			
Quadrant 3			
Quadrant 4			
Circle 1			
Circle 2			
Circle 3			
Circle 4			
Circle 5			
Quad 1 Cr 1			
Quad 1 Cr 2			
Quad 1 Cr 3			
Quad 1 Cr 4			
Quad 1 Cr 5			
Quad 2 Cr 1			
Quad 2 Cr 2			
Quad 2 Cr 3			
Quad 2 Cr 4			
Quad 2 Cr 5			
Quad 3 Cr 1			
Quad 3 Cr 2			
Quad 3 Cr 3			
Quad 3 Cr 4			
Quad 3 Cr 5			
Quad 4 Cr 1			
Quad 4 Cr 2			
Quad 4 Cr 3			
Quad 4 Cr 4			
Quad 4 Cr 5			

TABLE 35
COLOR ANALYSIS II

Color 10 Seconds Unsaturated vs Monochrome 10 Seconds Unsaturated

Indicates COLOR Better   Indicates MONOCHROME Better

SIGNIFICANT DIFFERENCES NOTED

Element	BATCH	SUB BATCH 1	SUB BATCH 2
Total			
Air			
Surface			
Submarine			
Friendly			
Hostile			
Neutral			
Fr Air			
Fr Surface			
Fr Submarine			
Hos Air			
Hos Surface			
Hos Submarine			
Neu Air			
Neu Surface			
Neu Submarine			
Quadrant 1			
Quadrant 2			
Quadrant 3			
Quadrant 4			
Circle 1			
Circle 2			
Circle 3			
Circle 4			
Circle 5			
Quad 1 Cr 1			
Quad 1 Cr 2			
Quad 1 Cr 3			
Quad 1 Cr 4			
Quad 1 Cr 5			
Quad 2 Cr 1			
Quad 2 Cr 2			
Quad 2 Cr 3			
Quad 2 Cr 4			
Quad 2 Cr 5			
Quad 3 Cr 1			
Quad 3 Cr 2			
Quad 3 Cr 3			
Quad 3 Cr 4			
Quad 3 Cr 5			
Quad 4 Cr 1			
Quad 4 Cr 2			
Quad 4 Cr 3			
Quad 4 Cr 4			
Quad 4 Cr 5			

TABLE 36

COLOR ANALYSIS III

Color 10 Seconds Saturated vs Monochrome 10 Seconds Saturated

Indicates COLOR Better Indicates MONOCHROME Better

SIGNIFICANT DIFFERENCES NOTED

Element	BATCH	SUB BATCH 1	SUB BATCH 2
Total			
Air			
Surface			
Submarine			
Friendly			
Hostile			
Neutral			
Fr Air			
Fr Surface			
Fr Submarine			
Hos Air			
Hos Surface			
Hos Submarine			
Neu Air			
Neu Surface			
Neu Submarine			
Quadrant 1			
Quadrant 2			
Quadrant 3			
Quadrant 4			
Circle 1			
Circle 2			
Circle 3			
Circle 4			
Circle 5			
Quad 1 Cr 1			
Quad 1 Cr 2			
Quad 1 Cr 3			
Quad 1 Cr 4			
Quad 1 Cr 5			
Quad 2 Cr 1			
Quad 2 Cr 2			
Quad 2 Cr 3			
Quad 2 Cr 4			
Quad 2 Cr 5			
Quad 3 Cr 1			
Quad 3 Cr 2			
Quad 3 Cr 3			
Quad 3 Cr 4			
Quad 3 Cr 5			
Quad 4 Cr 1			
Quad 4 Cr 2			
Quad 4 Cr 3			
Quad 4 Cr 4			
Quad 4 Cr 5			

TABLE 37

COLOR AND TIME ANALYSIS I

60 Seconds Unsaturated vs 60 Seconds Unsaturated Total

■ Indicates COLOR Better □ Indicates MONOCHROME Better

SIGNIFICANT DIFFERENCES NOTED

Element	BATCH	SUB BATCH 1	SUB BATCH 2
Air	□		■
Surface	□		
Submarine			□
Friendly	□	□	
Hostile			
Neutral			□
Fr Air			
Fr Surface	□	□	
Fr Submarine			
Hos Air			
Hos Surface			■
Hos Submarine	■	■	
Neu Air			
Neu Surface			
Neu Submarine	□	■	□
Quadrant 1			
Quadrant 2	□		
Quadrant 3			□
Quadrant 4			
Circle 1			
Circle 2		□	
Circle 3	□		
Circle 4		■	
Circle 5		■	
Quad 1 Cr 1			
Quad 1 Cr 2			
Quad 1 Cr 3			
Quad 1 Cr 4			
Quad 1 Cr 5			
Quad 2 Cr 1			
Quad 2 Cr 2			
Quad 2 Cr 3			
Quad 2 Cr 4			
Quad 2 Cr 5			
Quad 3 Cr 1			
Quad 3 Cr 2	□	□	
Quad 3 Cr 3	□		□
Quad 3 Cr 4			
Quad 3 Cr 5	□		
Quad 4 Cr 1			
Quad 4 Cr 2			
Quad 4 Cr 3	■	■	
Quad 4 Cr 4		■	
Quad 4 Cr 5			
Quad 4 Cr 5			

TABLE 38
COLOR AND TIME ANALYSIS II

Monochrome 60 Seconds Saturated vs Color 60 Seconds Saturated

Indicates COLOR Better Indicates MONOCHROME Better

SIGNIFICANT DIFFERENCES NOTED

Element	BATCH	SUB BATCH 1	SUB BATCH 2
Total			
Air			
Surface			
Submarine			
Friendly			
Hostile			
Neutral			
Fr Air			
Fr Surface			
Fr Submarine			
Hos Air			
Hos Surface			
Hos Submarine			
Neu Air			
Neu Surface			
Neu Submarine			
Quadrant 1			
Quadrant 2			
Quadrant 3			
Quadrant 4			
Circle 1			
Circle 2			
Circle 3			
Circle 4			
Circle 5			
Quad 1 Cr 1			
Quad 1 Cr 2			
Quad 1 Cr 3			
Quad 1 Cr 4			
Quad 1 Cr 5			
Quad 2 Cr 1			
Quad 2 Cr 2			
Quad 2 Cr 3			
Quad 2 Cr 4			
Quad 2 Cr 5			
Quad 3 Cr 1			
Quad 3 Cr 2			
Quad 3 Cr 3			
Quad 3 Cr 4			
Quad 3 Cr 5			
Quad 4 Cr 1			
Quad 4 Cr 2			
Quad 4 Cr 3			
Quad 4 Cr 4			
Quad 4 Cr 5			

TABLE 39

COLOR AND DENSITY ANALYSIS I

Monochrome 60 Seconds Saturated vs Color 60 Seconds Saturated

Indicates COLOR Better Indicates MONOCHROME Better

SIGNIFICANT DIFFERENCES NOTED

Element	BATCH	SUB BATCH 1	SUB BATCH 2
Total			
Air			
Surface			
Submarine			
Friendly			
Hostile			
Neutral			
Fr Air			
Fr Surface			
Fr Submarine			
Hos Air			
Hos Surface			
Hos Submarine			
Neu Air			
Neu Surface			
Neu Submarine			
Quadrant 1			
Quadrant 2			
Quadrant 3			
Quadrant 4			
Circle 1			
Circle 2			
Circle 3			
Circle 4			
Circle 5			
Quad 1 Cr 1			
Quad 1 Cr 2			
Quad 1 Cr 3			
Quad 1 Cr 4			
Quad 1 Cr 5			
Quad 2 Cr 1			
Quad 2 Cr 2			
Quad 2 Cr 3			
Quad 2 Cr 4			
Quad 2 Cr 5			
Quad 3 Cr 1			
Quad 3 Cr 2			
Quad 3 Cr 3			
Quad 3 Cr 4			
Quad 3 Cr 5			
Quad 4 Cr 1			
Quad 4 Cr 2			
Quad 4 Cr 3			
Quad 4 Cr 4			
Quad 4 Cr 5			

TABLE 40

COLOR AND DENSITY ANALYSIS II

10 Seconds Unsaturated vs 10 Seconds Unsaturated Total

Indicates COLOR Better   Indicates MONOCHROME Better

SIGNIFICANT DIFFERENCES NOTED

Element	BATCH	SUB BATCH 1	SUB BATCH 2
Air			
Surface			
Submarine			
Friendly			
Hostile			
Neutral			
Fr Air			
Fr Surface			
Fr Submarine			
Hos Air			
Hos Surface			
Hos Submarine			
Neu Air			
Neu Surface			
Neu Submarine			
Quadrant 1			
Quadrant 2			
Quadrant 3			
Quadrant 4			
Circle 1			
Circle 2			
Circle 3			
Circle 4			
Circle 5			
Quad 1 Cr 1			
Quad 1 Cr 2			
Quad 1 Cr 3			
Quad 1 Cr 4			
Quad 1 Cr 5			
Quad 2 Cr 1			
Quad 2 Cr 2			
Quad 2 Cr 3			
Quad 2 Cr 4			
Quad 2 Cr 5			
Quad 3 Cr 1			
Quad 3 Cr 2			
Quad 3 Cr 3			
Quad 3 Cr 4			
Quad 3 Cr 5			
Quad 4 Cr 1			
Quad 4 Cr 2			
Quad 4 Cr 3			
Quad 4 Cr 4			
Quad 4 Cr 5			
Quad 4 Cr 5			

TABLE 41
COLOR AND DENSITY ANALYSIS III

10 Seconds Saturated vs 10 Seconds Saturated Total

Indicates COLOR Better   Indicates MONOCHROME Better

SIGNIFICANT DIFFERENCES NOTED

Element	BATCH	SUB BATCH 1	SUB BATCH 2
Air			
Surface			
Submarine			
Friendly			
Hostile			
Neutral			
Fr Air			
Fr Surface			
Fr Submarine			
Hos Air			
Hos Surface			
Hos Submarine			
Neu Air			
Neu Surface			
Neu Submarine			
Quadrant 1			
Quadrant 2			
Quadrant 3			
Quadrant 4			
Circle 1			
Circle 2			
Circle 3			
Circle 4			
Circle 5			
Quad 1 Cr 1			
Quad 1 Cr 2			
Quad 1 Cr 3			
Quad 1 Cr 4			
Quad 1 Cr 5			
Quad 2 Cr 1			
Quad 2 Cr 2			
Quad 2 Cr 3			
Quad 2 Cr 4			
Quad 2 Cr 5			
Quad 3 Cr 1			
Quad 3 Cr 2			
Quad 3 Cr 3			
Quad 3 Cr 4			
Quad 3 Cr 5			
Quad 4 Cr 1			
Quad 4 Cr 2			
Quad 4 Cr 3			
Quad 4 Cr 4			
Quad 4 Cr 5			
Quad 4 Cr 5			

TABLE 42

COLOR-TIME-DENSITY ANALYSIS

60 Seconds Saturated vs 60 Seconds Saturated Total

Indicates COLOR Better Indicates MONOCHROME Better

Element	SIGNIFICANT BATCH	DIFFERENCES SUB BATCH 1	NOTED SUB BATCH 2
Air			
Surface			
Submarine			
Friendly			
Hostile			
Neutral			
Fr Air			
Fr Surface			
Fr Submarine			
Hos Air			
Hos Surface			
Hos Submarine			
Neu Air			
Neu Surface			
Neu Submarine			
Quadrant 1			
Quadrant 2			
Quadrant 3			
Quadrant 4			
Circle 1			
Circle 2			
Circle 3			
Circle 4			
Circle 5			
Quad 1 Cr 1			
Quad 1 Cr 2			
Quad 1 Cr 3			
Quad 1 Cr 4			
Quad 1 Cr 5			
Quad 2 Cr 1			
Quad 2 Cr 2			
Quad 2 Cr 3			
Quad 2 Cr 4			
Quad 2 Cr 5			
Quad 3 Cr 1			
Quad 3 Cr 2			
Quad 3 Cr 3			
Quad 3 Cr 4			
Quad 3 Cr 5			
Quad 4 Cr 1			
Quad 4 Cr 2			
Quad 4 Cr 3			
Quad 4 Cr 4			
Quad 4 Cr 5			
Quad 4 Cr 5			

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